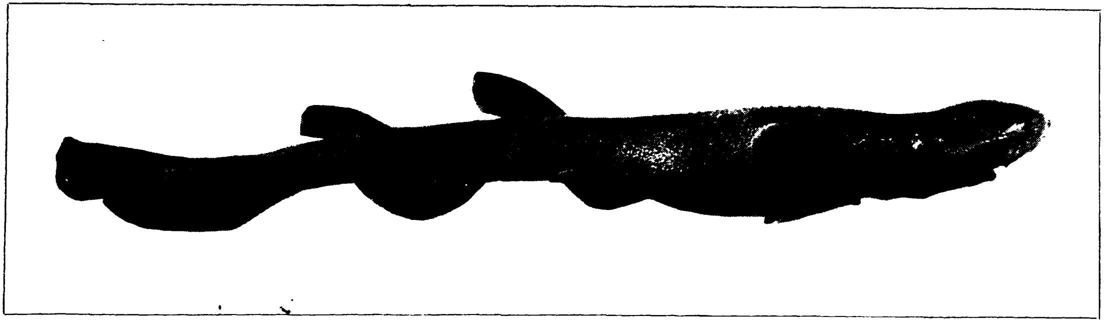
THE DISSECTION OF

THE DOGFISH



A Young Dogfish.

THE DISSECTION OF
THE DOGFISH

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PREFACE

In response to a continued demand for a book on the dissection of the dogfish on the lines of *The Dissection of the Frog* and *The Dissection of the Rabbit* the present volume is presented.

It is our hope that students and teachers will find the book as useful in their work on the dissection of the dogfish as the previous books have proved to be in connection with the dissection of the frog and rabbit. It has been written on similar lines, and the instructions have been given in the order in which dissections of the various systems can be taken when only one specimen is available. Teachers, however, will be able to take the dissections in any order they prefer, since each of them is complete in itself. Once more, we have not hesitated to incur, where necessary, slight repetition, with the conviction that such repetition is a distinct advantage.

We acknowledge with gratitude suggestions from several teachers of zoology. We have also derived much assistance in connection with the vascular system from the papers of Dr. C. H. O'Donoghue on The Venous System of the Dogfish (*Proc. Zool. Soc.*, June, 1914) and The Blood Vascular System of the Spiny Dogfish (*Trans. Roy. Soc. Edin.*, Vol. IV., Part III. (No. 33), 1928).

R. H. WHITEHOUSE,
LONDON, 1936. A. J. GROVE.

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ADVICE TO THE STUDENT

Laboratory Method

The system of instruction usually followed in colleges and schools consists of lectures combined with practical work. Most, one may say all, junior students—very often seniors too—find it none too easy to get full benefit from lectures, for strictly speaking, lectures of the serious type are of full benefit only to those who already know a great deal about the subject of the lectures. It is certain that you will miss a great deal of what you are told in lectures, for very few can listen to one thing and write another at the same time; thus you will have to depend on your reading and laboratory work to clear up things.

Do not go to the laboratory without having first prepared yourself in the work to be done. Go through your lecture notes and that part of your textbook concerned, as recommended in the Preparation section of this book. It is also advisable to read through the laboratory instructions so that you will be able to follow them more quickly when actually engaged in your practical work.

If you meet with any difficulty at all, do not fail to make a note of it and get it cleared up in the laboratory. One of the chief complaints about students' work which every demonstrator makes is that students will not ask questions. But, remember, do not ask questions the answers to which can be found very easily by consulting your textbook; get into the habit of searching books for references. Do not look upon your demonstrator as a labour-saving machine or an encyclopaedia.

The demonstrator will sit down beside you at your work, see what you have done and how you have done it; he will examine your drawings and note particularly your labelling and your laboratory notes; he will question you on the subject of your work, and will put you right where

you are wrong, or he will suggest improvements. He will answer your questions, and as he leaves you will tell you what he expects done by the time he next gets round to you. It is your business to make the most of his presence.

The laboratory is a workshop, and it is to your advantage to go on quietly with your work and make as much use of your opportunities as possible. Never leave the laboratory without getting every scrap of your records checked; the error in an incorrect entry is impressed on your mind every time you see it, but if your records are reliable, they are invaluable for revision and general study.

Your Tools

The choice of instruments is a matter of individual taste and the result of experience. The suggestions below, however, are recommended as a minimum.

1. One pair of large straight dissecting scissors with about 2 in. blade.

2. One pair of fine straight scissors with $1\frac{1}{4}$ in. blade. [*The scissors in which the halves can be separated are excellent, and can be more easily kept clean.*]

3. One large all-metal scalpel, 2 in. blade.

4. One medium all-metal scalpel, 1 in. blade.

5. One fine all-metal scalpel with narrow blade like a cataract knife.

6. One all-metal seeker of which the end must be rounded, not truncated or sharp. [*All-metal scalpels and seekers are recommended in preference to those with wooden handles, as the latter, sooner or later, break at the rivets.*]

7. Two mounted needles. [*Holders with a chuck can be purchased quite cheaply.*]

8. One pair of strong blunt forceps, preferably of stainless steel, 5 in. long.

9. One pair of medium fine point forceps, preferably stainless steel, about 4 in. long.

10. One pair of very fine point forceps, preferably stainless steel or heavily nickelled, with almost needle points. [*When purchasing see that the points meet exactly, and that they do not overlap when closed.*]

11. One aluminium section lifter.

12. One camel hair or sable brush.

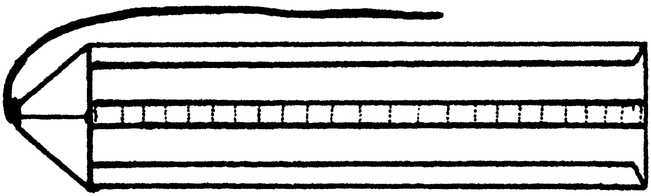
13. One pipette.

14. One pair of dividers for measuring.

15. One small steel rule.

16. One watchmaker's eyeglass, or mounted lens.

It is always desirable to have a duplicate set of scalpels, so that if one is dulled a sharp one is immediately available to continue dissection.



The most convenient case for instruments is a strip of baize or canvas with each of the long sides folded over as a loose flap, and a length of tape along the middle sewn down at about half-inch intervals. The finished article should be about seven inches wide and twelve to eighteen inches long, with a wrapping tape at one end.

This type of case has the advantage that additional instruments can be accommodated. The box type has very limited accommodation, and scalpels and scissors other than those supplied with the box rarely fit; it is also more costly.

Care of Instruments

Take the greatest care of your instruments and " neither a borrower nor a lender be."

Good dissection is quite impossible with dirty or blunt instruments. Use them *only* for the work for which they are intended. Here are a few hints:

1. Cut nothing but soft tissue with scalpels or scissors. (Use a pocket knife for sharpening pencils.)

2. Keep a special large scalpel for " rough " work, such as for cutting the skin of dogfish or for scraping.

3. Do not stick mounted needles by their points in the bench or dissecting board.

4. Carefully wipe all instruments dry after use, giving special attention to scissors round the rivet. (It is quite the best thing to wipe over cleaned instruments with an oiled rag.)

Sharpening of Scalpels and Scissors

Unless cutting instruments are in perfect condition, good dissection is impossible; blunt instruments are responsible for most " accidents " in dissecting, and it always pays to keep scalpels and scissors really sharp.

The secret of keeping scalpels and scissors in perfect condition is never to let them become badly dulled. Men strop razors every time after use because they know that a clean and comfortable shave is impossible with even a slightly dulled razor. Scalpels should be kept continually as sharp as a good razor. It is well worth practising until you are successful at sharpening scalpels on an oilstone.

With just a spot of oil on the stone, give a circular motion to the scalpel, holding it perfectly rigid and almost flat on the stone. Do this quite lightly and give only two or three rubs on each side alternately. Turn the scalpel over on its back, never on its edge—just as you would a razor.

The real test of sharpness is, of course, cutting cleanly, but if the edge of the scalpel can be seen edge-on with a lens, it is dull and needs sharpening.

Never let a scalpel get really dulled, and get into the habit of always examining the edge before use. If it is only slightly dull, a few seconds with the oil stone is quite sufficient, for it is usually only the tip that needs attention.

Scissors are, for most people, more difficult to sharpen, and it is usual, and perhaps advisable, to take them to an instrument maker for sharpening. However, with some practice, they are easy to keep in condition. Examine the angle of the cutting edge; then hold the blade on the stone in such a way as to preserve that angle—a variation from it will ruin the scissors. Keeping the blade absolutely fixed at the proper angle, take it along the stone in one direction only, away from you. Finish by putting the blade face down and flat on the stone to take off any burring of the edge. Special attention should be given to the points.

One word of warning regarding the oilstone: for scalpels, do not use the stone which is reserved for sharpening razors, because hollows will be worn in it and make it unfit for sharpening razors.

Drawings

Diagrams are intended to be a part of the record of your work, and if faithful they are invaluable for future reference. It is extremely foolish to copy textbook diagrams in place of original drawings from the specimen; by doing so you gain *nothing*, but lose one of the most valuable parts of your training. Every examiner in practical biology finds that many of the sketches given in practical tests are merely recollected textbook diagrams, and assesses them at their true value—O. A faithful diagram is at once appreciated by an examiner.

It is most important that students should realise that it is *diagrams* that are wanted, not attempts at pictures. Your diagram must be a graphic record of what another can find in the dissection; if it is not, it is valueless. And in order that the record may be readily interpreted, the topography needs to be given. This means that other structures than those specially to be illustrated should be indicated; for example, where the course of nerves is to be shown, neighbouring muscles or blood vessels which are useful as landmarks should be indicated. In the case of a diagram of the vascular system, a copy of

the stereotyped textbook figure is quite useless as a record of practical work.

In your own interest, therefore, scrupulously avoid copying textbook figures. When a specimen shows a variation from the normal, it would be fortunate for you in an examination if your drawing showed this with a note pointing out the abnormality.

All diagrams should be drawn in pencil, and colouring should rarely be used; really neat lines cannot be made with coloured crayons, but the chief objection is that errors in crayon cannot be corrected effectively. Black and white drawings are much neater. On rare occasions a slight amount of colouring might be an advantage, *e.g.* when several nerves and blood vessels run closely parallel, neat colouring of the vessels might be done *after* checking.

Wherever possible, draw the diagram of a system inside an outline of the body; this greatly assists correct proportion, and indicates the exact course taken by vessels, nerves, etc.

Avoid, wherever practicable, double lines to represent nerves, vessels, etc. They are usually unnecessary, are difficult to do neatly, and take more than double the time required for single lines.

Label your figures fully. Do this in very neat handwriting or in lettering, and write all names *horizontally.* Indication lines should go from the name *exactly* to the spot labelled, so that there can be no ambiguity; these lines should also be of such a nature as to be distinct from lines in the drawing; short-dash lines are perhaps the best; they should not cross.

Laboratory Notes

If your work is to be a training in scientific method, you must adopt the system of working characteristic of the investigator. After studying the results of previous investigators, he repeats their experiments with a view to verification, and in the course of his work makes diagrams *and* at every step keeps a written record of his observations. There are often points which a diagram alone cannot show;

there are difficulties to be reminded of in the future; there are methods of preparation and dissection; there are variations to be noted; and so on.

Thus a laboratory book should not be regarded merely as a book of diagrams; it must be a complete record of your work, and laboratory notes are quite as important as a record as are diagrams and labels. Further, for revision work, notes are invaluable.

Here is an illustration of a laboratory note, given as a guide to what is expected—

TEETH. Dermal denticles resembling those covering the body—larger, spines easily visible and directed towards the mouth cavity. Three rows. Upper and lower not opposed, lower engage on a pad behind the upper.

Function: To prevent escape of prey, not for biting or chewing.

The Use of a Dissecting Lens

You are advised to use constantly a watchmaker's eyeglass; this is preferable to a hand lens, since both hands are left free for dissection. And since it is possible that you have had little or no experience of the use of a watchmaker's eyeglass, you should practise holding one in position and continue to do so until you can safely lodge it without fear of its falling. Another important point is that you should use the glass with *both* eyes fully open; this will be easily possible with practice, just as it is in the case of a microscope; to screw up the eye which is not in use is very tiring and even injurious. For skilful dissection on a small animal, such an aid as a watchmaker's eyeglass is almost indispensable.

THE DISSECTION OF THE DOGFISH

[*SCYLLIUM CANICULA*]

SECTION I

PREPARATORY READING

You are strongly advised to read, before undertaking practical work, as much of the anatomy and physiology of the dogfish as you will have to study in the laboratory. To attend the laboratory without having at first a fair idea of what you are expected to display in dissection will result in mistakes and much slower progress.

Your reading should include as much as possible of that part of your study which is connected with your practical work; *e.g.* though you will not be able to study the details of digestion in the laboratory, you should read about it before dissecting the alimentary canal. In this way, your laboratory work will be much more intelligible and interesting.

Three commonly used textbooks have been chosen from which to offer you a guide to such reading. They are

(1) *Textbook of Zoology*, by Wells and Davies, University Tutorial Press, 1932 edition. This book is referred to under W. and D.

(2) *Manual of Zoology*, by Borradaile, Oxford University Press, 1935, *Eighth Edition*. This book is referred to under B.

(3) *Biology for Medical Students*, by Hentschel and Cook, Longmans, Green and Co., 1934. This book is referred to under H. and C.

The Skull

W. and D. Study pp, 195 to 197; section 12, and Fig. 99.

From the opening sentence it might be inferred that the jaws are not part of the visceral arches, but actually they are formed from the first visceral arch.

The palato-pterygoid is also called the palato-pterygo-quadrate.

In Fig. 99 only the prespiracular ligament is shown, the ethmo-palatine ligament having been omitted.

B. Study pp. 395 to 399, and Figs. 300 and 301. Cranium is here used to denote only the brain-box; some authors include sense capsules in this term.

The aqueductus vestibuli is also called the ductus endolymphaticus.

On p. 398, l. 14 from bottom, and Fig. 300, for post-spiracular ligament read prespiracular ligament.

H. and C. Study pp. 124 to 129, and Figs. 63 and 64.

p. 124. The term cranium is used here to denote the brain-box or neurocranium only. The term chondro-cranium is sometimes used to indicate the brain-box plus the sense capsules.

p. 128. The mandibular arch consists of four (two pairs) cartilages.

p. 129. Each branchial arch is made up of nine elements (four pairs and one median plate).

The Vertebral Column

W. and D. Study pp. 193 to 195; section 11 and Figs. 99 and 100.

B. Study pp. 393 (bottom) to 395, and Fig. 300.

p. 395. What is termed the neural arch in this description is frequently called the vertebral neural plate or basidorsal. The intercalary pieces correspond to the intervertebral neural plate or interdorsals.

H. and C. Study pp. 122 to 124, and Fig. 61.

p. 123. Interneural plate is the same as intervertebral neural plate or interdorsal.

In Fig. 61 B, the indication line of haemal arch should stop at the arch. It has passed into the haemal canal.

Pectoral Girdle and Fin

W. and D. Study pp. 197 to 198; section 13, and Fig. 101. The girdle is really composed of two halves fused in the middle line.

B. Study pp. 400 to 401 and Fig. 303.

p. 401. The fin rays are dermotrichia, and horny dermotrichia of the dogfish are ceratotrichia; actinotrichia are characteristic of larval Teleosts and sometimes are found at the edges of adult Teleost fins.

H. and C. Pp. 130 to 131, Fig. 65.

p. 130. Although the pectoral girdle is an inverted arch of cartilage in the adult fish, it is really composed of two halves fused together in the middle line and each half is made up of a coracoid and scapular portion.

Pelvic Girdle and Fin

W. and D. Study pp. 197 to 198, and Fig. 102.

p. 197. The pelvic girdle, too, is really composed of two halves fused in the middle line.

B. Study p. 401 and Fig. 304.

H. and C. Study pp. 131 to 132, and Fig. 66.

p. 131. Each half can really be divided into two portions as the bar is formed of two halves fused in the middle line.

External Features

W. and D. Study Chapter XV., sections 1, 2, and 3, pp. 183 to 185.

FORM AND APERTURES. Fig. 92, p. 183, is poor, especially the caudal fin. The end actually turns slightly upwards in the living fish. In section 1, in connection with the nostrils, note the reference to the absence of internal nares (nostrils).

See p. 184, top. Note "nasal fossae" = nasal pits, and that in function they are not respiratory. Note also the groove (oronasal groove).

Study section 3, p. 185, for sensory tubule (sensory mucous canal) openings and the lateral line. Note the function. See Fig. 94, p. 186.

The ductus endolymphaticus or aqueductus vestibuli is referred to at top of p. 203.

DERMAL DENTICLES. In section 2, p. 184, note that the authors refer to the basal plates of the dermal denticles as consisting of true bone. Few other authors are so definite. The important thing is the resemblance to the teeth of higher vertebrates, and you should consult Fig. 13, p. 60 for comparison.

Study Fig. 93, p. 184, and note how the basal plate is embedded in the dermis of the skin—under the epidermis. Note the pulp cavity and how blood vessels can enter through the pore in the basal plate.

CLASPERS. For a reference to the claspers in the male, see p. 204. Note that the vagina there referred to is the lower part of the oviduct. See Fig. 105, p. 202.

SENSORY TUBULES. See section 3, p. 185. Note the suggested function of this sensory system. See Fig. 63, p. 127 for ampullae of the ear—not labelled, but shown as swellings at the ends of the semicircular canals.

B. Study Chapter XXI., pp. 389 to 390 and 392. Note that the shape is adapted to aquatic life. You will see that the author regards the head as limited behind by the spiracle; this is not the usual view, since the skeleton of the gill pouches behind the spiracle is, strictly speaking, part of the skull.

Note how the scales resemble in structure the teeth of higher vertebrates, and compare Fig. 28, p. 54, which shows a section through a frog's tooth.

H. and C. Study Chapter VIII., pp. 82 to 87.

FORM. The adaptation of the fish's form to aquatic conditions is referred to on p. 84.

FINS. See p. 84. Note the function of the various fins. It would be advisable, in order to avoid possible confusion,

to use the term " ventral median fin " instead of " ventral fin," because some authors (we think inadvisably) call the pelvic fins " ventral fins." A homocercal fin need not necessarily be fan-like, *e.g.* in the eel. See p. 53 in this book.

Note the function of the claspers on the pelvic fins of the male dogfish.

APERTURES. Study pp. 84 to 86. Referring to the gill pouches (p. 85) note that the authors regard gill filaments and lamellae as synonymous. We have regarded the rows of filaments as constituting lamellae.

The ductus endolymphaticus opening is referred to on p. 120.

SKIN. See pp. 86 to 87. Note the absence of overlapping of scales shown in A, Fig. 42. The basal plate of the denticles is here said to be of cement, which is bone having lacunae and canaliculi with cells arranged in no definite order, and so unlike Haversian systems in true bone. Note the points of similarity to teeth—enamel, dentine, and pulp.

Body Wall

Textbooks refer only to the muscles and not to their vascular supply. You will study the veins in the laboratory if you are provided with a fresh specimen.

W. and D. Study section 4, pp. 185 to 186 and Fig. 94. No figure is given of the muscles of the body wall in a side view, so consult Fig. 20, p. 66 in this book.

For a reference to the siphon and its possible function in the male, see p. 204, last paragraph.

B. Study pp. 392 (bottom) to 393, on " Muscles and Movement." Notice particularly Fig. 299, p. 392, said to be part of the tail with the skin removed to show the arrangement of muscles. In the laboratory, examine your own specimen and see if the arrangement agrees with the figure, or whether the myotomes above the lateral line alternate with those below in this region. The arrangement

of the muscles is actually a little more complicated than shown in the figure because the dissection shown does not extend to the mid-dorsal line. The text says each myomere (myotome) is bent four times, but if you carry the dissection to the mid-dorsal and mid-ventral lines, you will find that each myomere bends yet once more than is shown in the figure, both dorsally and ventrally, making the number of bends six.

Note the effect of the heterocercal type of tail given here, viz. that it keeps the head down. Undoubtedly it keeps the tail up, but that is not quite the same thing as keeping the head down. The shape and angle of the underside of the head both tend to cause the head to rise during rapid propulsion.

H. and C. See p. 87, middle paragraph and Fig. 43. The zig-zag arrangement referred to is actually more complicated than shown, since the dissection illustrated does not extend to the mid-dorsal line. Refer also to Fig. 20, p. 66, in this book.

No mention is made of the siphon in the male.

The Abdominal Viscera and Alimentary Canal

W. and D. Study sections 5 and 6, pp. 187 to 188. Note the warning that the pericardio-peritoneal septum is not comparable to the diaphragm of mammals.

In section 6, p. 187, the "mouth" is spoken of as a cavity. It is more correct zoologically to speak of the mouth as the opening only, and the cavity to which it leads as the buccal cavity.

The basihyal plate mentioned is the tongue which is supported by the basihyal plate of cartilage. Note the limit of the pharynx anteriorly. Study Fig. 94 for the relative positions of organs; but it is unfortunate that the liver is not shown, for it occupies the greater part of the space labelled "coelom," and extends almost the whole length of the body cavity.

Note reference to rectal gland and suggested function, p. 188, bottom, but do not regard it as accepted opinion.

B. Study pp. 401 to 405. A possible difference of opinion may be mentioned in regard to the opening remarks on "The Coelom and Alimentary System." In conformity with the posterior limit of the head as given on p. 389, the pericardial cavity is said to occupy a position in the trunk; but note that the pericardial cavity with the heart is ventral to the pharynx, and the pharynx is scarcely to be regarded as part of the trunk. Further, the author uses the term "perivisceral cavity" to include both the pericardial cavity and the peritoneal cavity. More usually, perivisceral cavity signifies the peritoneal cavity.

Note the limits of the buccal cavity (here called "mouth," which strictly speaking is the aperture only) and pharynx, indicated by the spiracle. Note the remark on the slanting direction of the gill pouches.

Fig. 306, p. 403, is an excellent illustration of the disposal of the viscera. Study it carefully.

H. and C. Study pp. 87 (bottom) to 91. These authors consider the pericardial cavity as lying in the trunk. [See under B. above.] We have preferred (see p. 50) to regard the branchial region as part of the head.

Note the function of the pylorus and the paragraph (pp. 90 to 91) dealing with digestion. Fig. 44 is well worth study.

The Vascular Supply of the Alimentary Canal

It is strange that such an important system as the hepatic portal system receives such scant attention in textbooks. You are advised to read through pp. 86 to 90 in this book.

W. and D. Very little is given concerning the vascular supply of the alimentary canal of the dogfish. On p. 191 a brief reference is made to the four arteries from the dorsal aorta to the gut. On p. 193 only the hepatic portal vein is mentioned and nothing is said of its tributaries.

You are advised to refer to pp. 26 and 27 where the hepatic portal system is dealt with in the rabbit. The

principles apply equally to the dogfish, and note particularly the last paragraph of the section.

B. See p. 413, end of paragraph on "Arteries." A short reference is made to the arteries supplying the gut. The anterior mesenteric artery is said to give off a genital branch, but this latter arises from the coeliac artery. See Fig. 313, p. 412.

On p. 415 (middle) mention is made only of the hepatic portal vein, and nothing is said of its tributaries. But the features of a portal system are given on p. 68, in connection with the frog.

H. and C. See p. 96, where the coeliac, anterior mesenteric, and lienogastric arteries are mentioned, but no reference is made to the posterior mesenteric artery to the rectal gland.

Nothing beyond a mention is made, on p. 98, of the hepatic portal vein. Note particularly the characters of a portal system given on the same page.

The Vascular System

THE HEART AND VENOUS SYSTEM. Most of the diagrams of the venous system of the dogfish given in textbooks are inaccurate in detail, and you will be able to correct them from your own dissection.

W. and D. Study sections 8 to 10, pp. 190 to 193. In section 8, p. 190, note that the authors call the conus arteriosus plus the ventral aorta " truncus arteriosus," and speak of the ventral aorta as a bulbus or synangium. This is unusual, and you are advised to use the terms conus arteriosus and ventral aorta only.

In section 10, p. 191, the authors refer to " the hepatic sinus," but really there are two sinuses, side by side, separated it is true by an imperfect septum; note that there is a pair of openings into the sinus venosus, one for each sinus.

The inferior jugular vein is large and indefinite enough to constitute a sinus.

You will discover that the subclavian vein does not open into the posterior cardinal sinus as stated, but into the Cuvierian duct (sinus); it has no connection with the posterior cardinal sinus.

No mention is made of the lateral abdominal vein.

B. Study p. 410, 1st paragraph on " Blood Vessels: Heart," and the paragraph on " Veins," pp. 413 to 415.

The pericardium is here spoken of as the cavity in which the heart lies. Since the pericardium is only a membrane which lines the cavity in which the heart lies, it is more correct to speak of the cavity as the pericardial cavity. See p. 60 where the heart of the frog is dealt with. The remarks on the pericardium there, where it is described as " a thin sac," are equally applicable to the dogfish. Hence in all vertebrates the pericardium is a membranous sac and not a cavity.

The remarks on the veins and the diagram (Fig. 314) need some correction, which you will be able to verify in your dissection.

(1) The subclavian vein does not enter the posterior cardinal sinus as shown in the figure, but enters the ductus Cuvieri where the vessel labelled *d.l.s.* enters.

(2) The deep lateral sinus (*d.l.s.*) is usually called the lateral abdominal vein nowadays. This vessel joins a transverse vessel which runs just behind the pectoral girdle.

(3) The brachial sinus also joins the transverse vessel mentioned and the combined vessels form the subclavian vein. In the diagram given, the anterior part of the deep lateral sinus, or lateral abdominal vein, would be more accurately called subclavian vein.

(4) The two posterior cardinal sinuses arise between the kidneys as a single sinus.

(5) The renal portal veins will be found to pass along the inner edges of the kidneys, not on the outer as shown. Consult Fig. 47 in this book.

H. and C. Study pp. 93 to 94 on the heart, and pp. 96 to 99 on the venous system.

In the venous system, the diagram (Fig. 49) on p. 97 is essentially correct, but there are two differences which you will notice in your dissection. (1) The lateral abdominal veins come nearer together anteriorly and join a transverse vessel just behind the pectoral girdle (cf. a similar transverse anastomosis at the pelvic girdle). The brachial vein (sinus) also joins this transverse vessel, and the two form the subclavian vein. See Fig. 22 in this book. (2) You will find that the renal portal veins run along the inner edges of the kidneys and not on the outer sides, the forking of the caudal vein being very slight at the kidneys.

THE ARTERIAL SYSTEM. This system involves the question of respiration, and it would be as well if you realise that respiration is not synonymous with breathing. Breathing is the process by which a gaseous exchange takes place—oxygen being taken in and carbon dioxide being eliminated. But that is not all of the respiratory process. Respiration involves the liberation of energy by the oxidation of food materials; the complex organic substances are broken down into simpler substances, and this breaking down releases energy, which is used up in enabling all the activities of the animal body to be maintained. Hence, in considering the gills and their vascular supply, remember that only a part of the respiratory process takes place in the gills, viz. the acquisition of oxygen in exchange for carbon dioxide eliminated, so that the real respiratory process of oxidation of food material with the release of energy can be effected.

W. and D. Study section 7, p. 189, and section 9, p. 191. Note particularly the mechanism of breathing in section 7. The second paragraph of section 9, p. 191, needs a little modification. The "nine vessels" referred to really consist of four complete loops plus a half loop, the half loop serving the hemibranch of the 5th gill cleft. These loops are the efferent branchial arteries, and they all contribute to the formation of four epibranchial arteries

in the roof of the pharynx. Incidentally, in Fig. 98, p. 192, the arrangement of the vessels at the gills is essentially correct, *but* it is possible that you may at first sight think that the hemibranch is at the anterior end. So note carefully that each gill pouch is surrounded by the efferent branchial loop. The last efferent vessel does not join the loop at the dorsal end as shown, but joins by vessels crossing the 4th branchial arch at various places; such connecting vessels are called anastomoses.

B. Study pp. 401 (bottom) to 404 for a reference to the gills. Consult Fig. 311, p. 409, which clearly shows the afferent branchial arteries to the gills—the figure is a good representation of what you will be expected to display in dissection.

Then study pp. 410 to 413 and consult Fig. 312, p. 411. Note the warning footnote on p. 413. In this book we have called the vessel labelled " carotid artery " in Fig. 312 internal carotid, and you should note that " external carotid " is given in quotation marks; the alternative suggested, viz. orbital, is a good name, for it is certainly not an external carotid artery. The vessel has been called stapedial artery by O'Donoghue because it is homologous with a vessel of that name in mammals. However, since there is no stapes in the dogfish the name stapedial is not descriptive.

H. and C. Study pp. 91 to 92 for a description of the gills and breathing movements, and pp. 94 to 96 for the arterial system.

The authors call by the names " common carotid " and " external carotid " arteries, vessels which are not nowadays justifiably so called. The external carotid artery arises from the *ventral* end of the first efferent loop. See note under B. above. On p. 96 the authors refer to genital arteries to the gonads as arising from the posterior part of the dorsal aorta. If such are found they are accessories, since the principal genital arteries are branches of the coeliac artery.

The Renal and Reproductive Organs

When you dissect the male reproductive organs, you will probably be puzzled as to the function of certain parts. Indeed it is a little difficult to interpret the uses of some of the parts; *e.g.* you may find it of interest to think out (1) how the sperms get into the duct of the clasper; (2) what part the siphon plays; (3) the use of the sperm sac, which is said never to contain spermatozoa.

W. and D. Study sections 18 and 19, pp. 203 to 206, and consult Figs. 105, 106, and 107.

The confluence of the posterior ends of the testes referred to is only present in mature adults. In the young and immature males these organs are entirely separate. Note that the testes are quite separate in Fig. 107.

When you dissect a male dogfish, you will find that the " urogenital sinus " referred to (it would be more accurate to say urinogenital sinus) is a very small chamber formed by the confluence of the two sperm sacs. And you will find that the urinary and genital apertures actually open into the hind part of the sperm sac on each side.

In section 19, p. 205, you will read that the kidney is divisible into an anterior non-renal mesonephros and a posterior functional kidney or metanephros. Many writers nowadays refuse to regard the posterior part as metanephros, and consider the whole of the kidney in the dogfish to be mesonephros, on the grounds that a metanephros is not distinguishable during development. Other authors appear to evade the issue and guardedly speak of the posterior functional kidney as an opisthonephros or " after-kidney," and perhaps this is the wisest course.

See section 20, p. 206 for a reference to the supra-renal and inter-renal glands.

B. Study pp. 405 (bottom) to 410 (top). The Wolffian duct = vas deferens. Note that the author does not commit himself in regard to the name metanephros as applied to the posterior part of the kidney. Read the footnote on pp. 407 and 408. It may be said that

few zoologists nowadays consider that a metanephros is present. The name opisthonephros avoids the difficulty.

In your dissection of the male organs, you will find that the ureter and the vesicula seminalis on each side open separately, but close together, into the entrance to the sperm sac. In Fig. 309, p. 407, the two openings are rather more widely separated than is actually the case. Note also that the testes are shown as entirely separate, but in the mature male they are united at their posterior ends.

No mention is made of the siphon in the male.

See p. 425 for a reference to the supra-renal and inter-renal glands.

H. and C. Study pp. 99 to 105.

A definite opinion is expressed that in the dogfish the kidney is wholly mesonephros. See remarks above.

No mention is made of the siphon in the male, nor is there any reference to the supra-renal and inter-renal glands.

Cranial Nerves

W. and D. Study pp. 200 to 201, section 16, and Fig. 103. The alternative name *vidian*, l. 7, p. 201, is unnecessary.

B. Study pp. 418 to 425 and Figs. 302 (p. 397), and 316 to 320. Note that " Fig. 265 " in the legend of Fig. 320 is a misprint for " Fig. 319."

H. and C. Study pp. 110 to 114 and Figs. 56, 57, and 58. The hyoidean branch of No. VII. is more commonly called the hyomandibular branch, since the postspiracular element divides into hyoidean and mandibular branches.

Brain

W. and D. Study pp. 198 to 200, section 15 and Figs. 103 and 104.

In Fig. 103, the separate diagram of the auditory organ lacks the ductus endolymphaticus.

B. Study pp. 415 to 418 and Figs. 302 (p. 397), 316 and 317.

p. 415. The cerebrum in the dogfish is frequently called the telencephalon.

The term pituitary body is also used to denote the whole structure formed by the fusion of the infundibulum and hypophysis.

H. and C. Study pp. 105 to 110 and Fig. 55.

p. 109. Hypophysis cerebri here refers to the infundibulum. Hypophysis more usually refers to that upgrowth from the buccal cavity which, on fusion with the infundibular downgrowth from the thalamencephalon forms the pituitary body.

SECTION II

LABORATORY WORK

ZOOLOGICAL IMPORTANCE

The dogfish is chosen for study because it is representative of the lower vertebrates. It belongs to the *Elasmobranchii*, a sub-class of Fishes (Pisces). Its interest lies in characters which resemble in some degree those which we have reason to believe were features of the primitive vertebrate ancestors. In addition to these primitive characters, the dogfish possesses characters which have evolved during many, many thousands of years in response to peculiar needs as they arose. There are thus two sets of characters to be kept in mind, primitive and specialised.

It is because the dogfish provides us with so many primitive features for study that it is chosen among fishes in preference to one of the more commonly edible fishes such as the herring, mullet, trout, or whiting, which are much more specialised than the dogfish. It is obviously better first to study the simpler type in order that we may better understand the highly specialised characters of the higher fishes. And the dogfish and its close relatives are, fortunately, very common inhabitants of the seas all over the world.

FRESH AND PRESERVED SPECIMENS

In almost every particular, fresh specimens are preferable to preserved. In the first instance they are cheaper, their cost being about half that of preserved animals, for preservation requires expert treatment as well as expensive preservative. For external characters, the fresh specimen is complete, while the preserved ones have the greater part of the tail removed and with it, of course, the fins it bears.

In the fresh dogfish the mouth can be opened without difficulty and the interior is easily examined; after preservation this is usually quite impossible. In preserved specimens most of the ventral body wall has been removed as a rule, and dissection to a varying extent has been made at the pectoral girdle. Thus the musculature, blood vessels and, in the male, the "siphon" have been destroyed. The vascular system can be much better studied in the fresh specimen, in particular that connected with the viscera. Fresh specimens are therefore strongly to be recommended.

It is most important, however, that fresh specimens should be ordered so as to arrive only just before they are required for dissection. It occasionally happens that, if the fresh fish has been left unopened for some time, the stomach will be found to have disintegrated by auto-digestion and become useless for dissection. This can be avoided to a great extent by opening the fish as soon as possible.

Washing of Fresh Specimens

Fresh specimens are the better for a washing to remove slime. Slime is usually plentiful inside the mouth and in the gill slits. Removal of the slime is best accomplished by holding the fish vertically over a sink, with the head downwards, and allowing a strong current of water from the tap to enter the gill slits in succession. If the mouth has been opened, the slime will be carried away by the current.

SKELETON

The skeleton of the dogfish, as in all vertebrates, consists of the axial skeleton, comprising the skull and vertebral column, and the appendicular skeleton, which includes the skeleton of the paired fins and the girdles which support them. The whole of the skeleton is composed of cartilage which, in parts, may have depositions of calcareous salts in the matrix—calcified cartilage—but no true bone is present.

THE AXIAL SKELETON

The Skull

The cephalic skeleton of the dogfish, by reason of, firstly the aquatic habit of the animal, and secondly its relatively primitive condition, presents many features of interest and points for comparison with the higher vertebrates. It includes the **cranium** or brain-box with the **sense capsules** and the **visceral skeleton** consisting of the jaws, hyoid arch and branchial arches. These collectively may be included under the term skull, though it will be realised that the term here may seem to have a different connotation from the usual; but actually it is morphologically accurate. As the examination of the skull proceeds, it will be noticed that the relationship between the cranium and the visceral skeleton is not so close as it is in the higher vertebrates, since the jaws are not fused with the cranium nor, in fact, do they articulate directly with it.

The Cranium. This is a roughly oblong trough or box of cartilage, complete below but incomplete above, to which have fused the olfactory capsules in front and the auditory capsules behind. At the sides of the trough, lying between the olfactory and auditory capsules, are depressions called the orbits, in which the eyeballs are lodged. The optic capsule does not fuse with the cranium

but is represented in the adult animal by the sclerotic coat of the eyeball.

Examine a cranium, and you will notice that it can be completely separated from the remainder of the cephalic

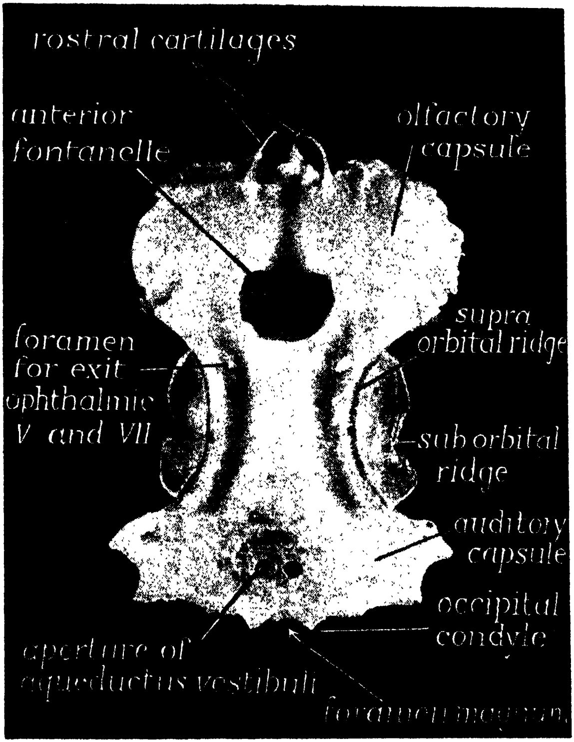


Fig 1.—The chondrocranium from above.

skeleton. Note that it is composed entirely of cartilage, rather thick at the hinder end but thinner anteriorly. Because of the fact that the cranium is composed only of cartilage, it is usually referred to as a **chondrocranium.**

Make out first the main regions of the chondrocranium. The central portion is the brain-box (sometimes called the neuro-cranium) in which the brain lies. Fused to its hinder end so as to be almost indistinguishable from it, are two solid-looking pieces of cartilage, the **auditory capsules**; and anteriorly, the rather larger, thinner, **olfactory capsules.** The brain-box, it will now be seen, is completely closed below, but on the dorsal surface there is the **anterior fontanelle**, a large oval or almost circular aperture which, in the living animal, is closed by a sheet of membrane. At the posterior end, however, the brain-box is roofed over with cartilage, but at the extreme end is a moderately large aperture, the **foramen magnum.** On each side of this aperture, but towards the lower half, will be seen a rounded knob. This is the **occipital condyle** by which the cranium articulates with the vertebral column. There is, however, no free movement at this articulation, for the cranium and column are bound together by fibrous material.

The **olfactory capsules** are roughly hemispherical in shape, the domed surface being uppermost. Below, the cavity of the capsules are widely open, and here, in the living animal, are the external nares or nostrils. On looking into the cavities of the capsules, you will see that they are in direct communication with the cranial cavity, but the two capsules are separated from each other by a vertical strip of cartilage, the **internasal septum** or **mesethmoid cartilage.** Projecting forwards from the front of the cranium will be seen three slender rods of cartilage, the **rostral cartilages,** which lie in the snout. The two upper cartilages arise, one from each olfactory capsule, but the lower one arises from the internasal septum or mesethmoid cartilage.

The **auditory capsules** are more solidly built. In each capsule is an aperture—the aperture through which passes the **ductus endolymphaticus** or **aqueductus vestibuli** on its way to the exterior. These apertures will be found one on each side of the median line at the hinder end of the cranium. Take a seeker or bristle and pass it into one of the apertures. You will find that it will pass into the capsule but does not

easily enter the cranial cavity. In the living animal, these apertures are covered over by the skin and are not ordinarily visible on the surface of the head. On the dorsal surface of

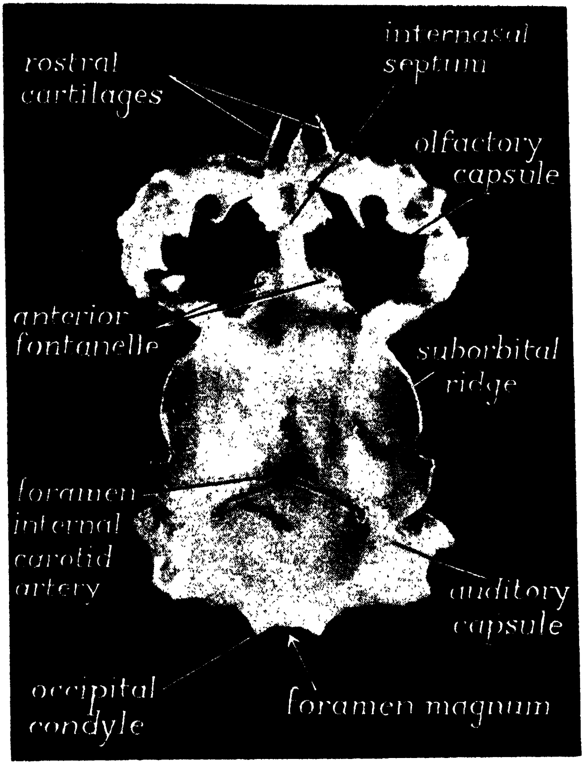


Fig. 2.—The chondrocranium from below.

each capsule two ridges can usually be distinguished at right angles to one another and placed obliquely to the long axis of the body. These ridges indicate the positions of the vertical semicircular canals of the membranous

labyrinth of the inner ear. No direct communication between the cavity of the auditory capsule and the cranial cavity can be seen except in a section through the median plane of the cranium, for the only connection is the foramen through which the auditory nerve passes.

The **orbits** are somewhat shallow concave depressions at the sides of the cranium, and occupy practically the whole of the space between the olfactory and auditory capsules. The upper margin of the concavity—the **supra-orbital ridge**—is formed by a thin lateral extension of the cartilage of the upper surface of the cranium. The lower margin—the sub- or **infra-orbital ridge**—is similarly an extension of the lower surface of the cranium.

On the under side of each auditory capsule will be found a groove or depression into which fits the proximal end of the hyomandibular cartilage—the proximal cartilage of the hyoid arch, which will be described under the visceral skeleton. This is fastened to the cranium by ligaments. The depression marks the only place where the visceral skeleton is in direct connection with the cranium. All other connections between them are by ligaments alone.

The Apertures of the Cranium. The positions of the foramen magnum and the apertures of the endolymphatic ducts have already been noticed. There are, however, many more apertures in the cranium, chiefly foramina through which the cranial nerves issue from the cranial cavity. As most of these are found in the orbit, it is best to begin with them.

Looking straight into the orbit from the lateral aspect, two large apertures will be seen in the lower part of the concavity, one in the anterior half of the orbit and the other in the posterior half. The more anterior foramen is that through which the second cranial nerve, the optic nerve, issues from the cranium to pass to the eyeball. Through the more posterior foramen pass the sixth and the larger branches of the fifth and seventh nerves. These two apertures serve as useful landmarks in the identification of the others. In the lower part of the orbit two apertures

will be noticed almost in line with the more posterior large aperture already identified. The lowest of these three transmits the "hyoidean" artery, and the middle one is the aperture of the interorbital canal, a canal by which the two orbits are placed in communication with each other. By means of this canal, the blood in one orbital sinus can pass to the other. Take a bristle and pass it in at one aperture, when it will be found to emerge at the corresponding

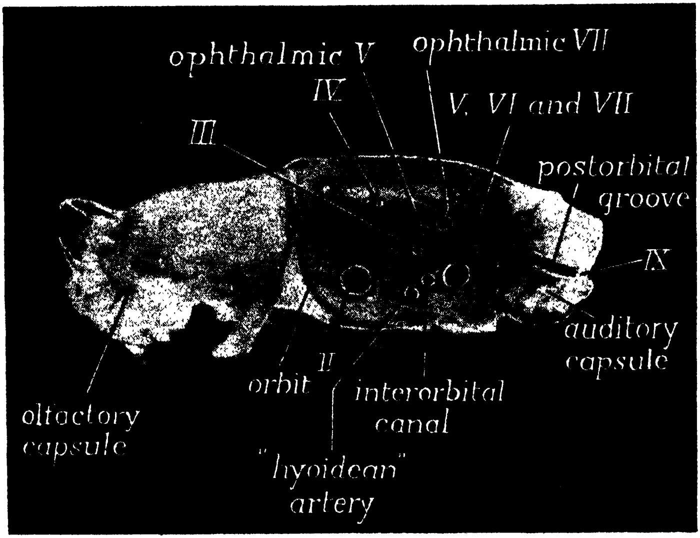


Fig. 3.—The chondrocranium from the side.

aperture of the other orbit. Anterior to these three apertures is another series of three apertures, almost in a line but making an acute angle with that of the three you have just examined. The lowermost of these is the foramen of the third cranial nerve, the middle one that of the ophthalmic branch of the fifth, and the uppermost one that of the ophthalmic branch of the seventh cranial nerve. The last two can be readily identified by the grooves

in front of them, in which the nerves lie. These grooves approach each other, and at the anterior end of the orbit join, to pass to an aperture which leads to the surface of the cranium. Identify the position of this aperture and pass a seeker through it from above and note where it enters the orbit.

Below the grooves in relation with the foramina of the ophthalmic branches of the fifth and seventh nerves and a little beyond half-way between those foramina and the aperture leading to the surface of the cranium is a small foramen through which the fourth nerve enters the orbit. As it is quite small, this aperture is not easy to find unless the specimen has been well cleaned.

At the anterior part of the orbit is a moderate sized foramen opening into the cavity of the nasal capsule. This is the **orbito-nasal foramen** through which the orbital blood sinus communicates with a sinus in relation with the olfactory organ. Take a seeker and pass it through the foramen, and note where it appears in the olfactory capsule. There is similarly a channel of communication between the orbital sinus and the anterior cardinal sinus; this, however, is not by a foramen but by a groove—the **post-orbital groove**—passing on the outside of the auditory capsule from the posterior margin of the orbit.

Of the other foramina of the cranium, that of the ninth cranial nerve is found in the hinder part of the post-orbital groove. Put a bristle into it, and you will find that the bristle will pass through a canal in the cartilage of the auditory capsule, and appear—as can be seen through the foramen magnum—in the hinder part of the cranial cavity. The foramina of the tenth nerves will be seen, one on each side of the foramen magnum, each at the bottom of a depression in the cartilage. Put in a bristle and note where it appears in the cranial cavity.

On the ventral side of the hinder end of the cranium there can also usually be seen shallow grooves in which, in life, certain arteries lie, and in relation with them are three apertures. The middle one transmits the internal carotid artery. The two outer ones lie in the infra-orbital

ridges and through each passes a branch[1] of the internal carotid artery.

Drawings.—The most instructive drawings are the dorsal, ventral, and lateral views. That of the lateral view should be fairly large so that the apertures in the orbit can be included.

THE VISCERAL SKELETON

The visceral skeleton consists of a series of **visceral arches** formed in relation with, and giving support to, chiefly the pharynx. Typically, each arch is made up of two halves joined together in the mid-ventral line and lying in the mesoderm of the pharyngeal wall between the **visceral clefts.** In the dogfish most of these visceral clefts subserve a respiratory function, and are consequently called gill clefts. Each half of the arch is, primitively, composed of several pieces, movable upon one another, the movement being effected by muscles.

The first arch is the **mandibular arch** which borders the mouth.

The second arch is the **hyoid arch,** and between it and the mandibular arch lies the hyomandibular visceral cleft or **spiracle.**

The remaining five arches are the **branchial arches** between the five gill clefts.

Of these visceral arches, the first two have been specially modified, the mandibular arch to form the upper and lower jaws and the hyoid arch to function as the suspensorium of the jaws and the support of the floor of the buccal cavity. It is the only visceral arch to be articulated directly with the cranium. All the other arches have no direct connection with either cranium or vertebral column.

The specimens of the visceral skeleton commonly used for class work, whether they are isolated or have the cranium left in position, are frequently difficult to interpret

[1] This branch is called by some authorities the stapedial artery, but this name has, of course, no morphological significance in the dogfish. (See p. 18.)

because the normal dorso-ventral compression of the parts has been accentuated during preparation. The examination therefore is greatly facilitated if some cylindrical

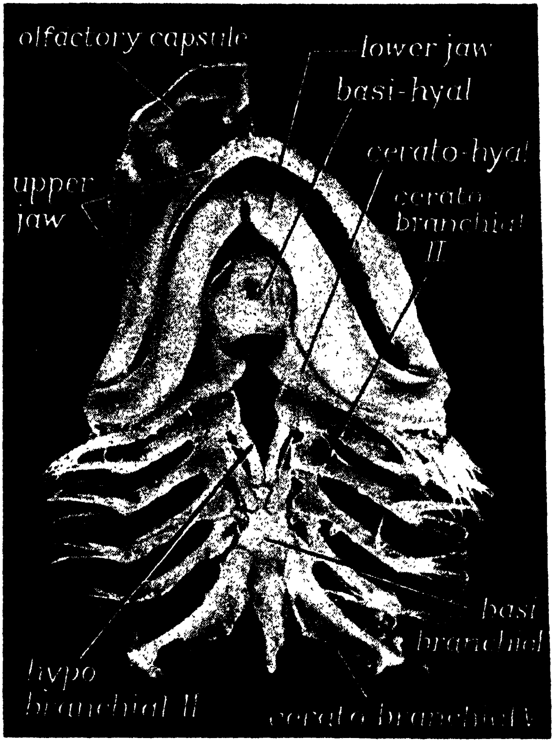


Fig. 4.—The visceral skeleton from below. The olfactory capsule of one side has been removed.

object such as a glass specimen tube is passed between the jaws and pushed far enough back through the branchial skeleton as to separate the dorsally situated portions from those lying ventrally.

The most convenient way to examine the specimen is first to consider each arch separately as indicated below.

The Mandibular Arch

This, as has already been stated, includes the upper and lower jaws so that each half consists of two pieces of cartilage articulating with one another behind—and fastened together by ligaments—the two halves meeting in the middle line above and below the mouth. The **upper jaw**, then, consists of two stout pieces of cartilage, each of which tapers anteriorly where it joins its fellow of the opposite side, and broadens posteriorly where it articulates with the corresponding side of the lower jaw. It is not divisible into regions, and the whole of its surface is smooth with the exception of a knob-like protuberance on its upper inner face. Each cartilage is sometimes called the **palato-pterygo-quadrate cartilage,** a name which has little significance in the dogfish, but is applied to the comparable structure in the embryo of higher vertebrates.

The **lower jaw,** similarly, is made up of a pair of cartilages, somewhat stouter even than those of the upper jaw, meeting in front and articulating with the upper jaw behind. These, too, are narrower in front and broaden considerably posteriorly. Each is called **Meckel's cartilage.**

The Hyoid Arch

The hyoid arch is not so easy to follow as it is in close relation with, and partly hidden by, the jaws. It consists of five pieces of cartilage in all; a median plate, the basihyal, to which are attached the paired ceratohyals, dorsal to which lie the hyomandibular cartilages. Looking at the specimen from the ventral aspect, gently separate the lower jaws and between them will be seen a thin plate of cartilage, semicircular in outline in front and having a foramen in the centre. This is the **basihyal cartilage.** Attached to the posterior border of the basihyal and partly overlapping it, is a pair of **ceratohyals** which pass

outwards beneath the posterior margin of the lower jaw to the points of articulation with the upper jaw. Both hyomandibular and ceratohyal cartilages have arising from them slender branching cartilages, the **branchial** or **gill rays,** which support the gills. By turning the specimen over, it will be seen that there is a stout, short cartilage on each side attached at its ventral or distal end to the ceratohyal and dorsally or proximally—if the cranium is included in the preparation—to the under side of the auditory capsule. Each is a **hyomandibular cartilage.**

It will thus be seen that the hyoid arch is directly articulated with the cranium—the only visceral arch to be so—and is also attached by ligaments to the articular ends of the upper and lower jaws. Consequently, the hyomandibular cartilage forms the suspensorium of the upper and lower jaws which have no direct skeletal connection with the cranium. This arrangement is characteristic of that type of skull which is termed **hyostylic.** The upper jaw is connected with the cranium by ligaments of which there are two pairs; the **ethmo-palatine ligaments** and the **pre-spiracular ligaments.** Each ethmo-palatine ligament is attached at its distal end to the knob-like protuberance on the inner face of the upper jaw, and at its proximal end to the under side of the cranium at the anterior margin of the orbit. Each pre-spiracular ligament stretches from the posterior end of the upper jaw to the anterior part of the auditory capsule. Usually these ligaments have been removed in the preparation of the visceral skeleton, so that you will not find them in your specimen. They are, however, frequently included in the diagrams in your textbook, which you may consult to confirm their position.

The Branchial Arches

Typically, each branchial arch (Fig. 5) consists of nine pieces of cartilage; a median basal piece, the **basi-branchial,** and four pairs of cartilages, in order of sequence, the **hypo-, cerato-, epi-,** and **pharyngo-branchials** attached end to end to one another, and the hypo-branchials joined to the basi-branchial. Each branchial arch thus constituted,

would form a cartilaginous support lying in the wall of the pharynx in the septum between successive gill pouches. However, in the dogfish there has been some fusion and suppression, for all these cartilages will not be found in all the arches. The basi-branchial portions of all the arches are represented by a single, somewhat triangular cartilage which lies in the mid-ventral line in the floor of the pharynx. Examine the ventral side of your specimen, and you will be able to identify the basibranchial lying between the two halves of the hindermost arch. Now, in order to familiarise yourself with the arrangement of the cartilages in one arch

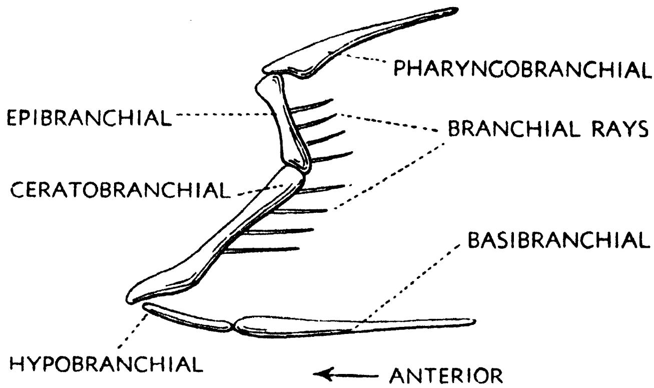


Fig. 5.—Diagram of the cartilages of the second branchial arch.

take the second branchial arch. Arising obliquely from the front end of the basibranchial will be seen, directed forwards, two short slender cartilages, the hypobranchials of the second arch. Confining your attention now to one side of the arch, you will see passing obliquely *backwards* the ceratobranchial, which is easily identified if the specimen is complete, by the slender branchial rays attached to it. Now, turning the specimen so that you can see the dorsal side of the arch, you will find that the ceratobranchial leads to a short cartilage, the epibranchial—also with branchial rays—following much the same direction as the

ceratobranchial. Attached to the epibranchial is a slender tapering pharyngobranchial, which is directed markedly backwards, completing this side of the arch.

You are now in a position to visualise one complete arch, and can examine the others in order.

In the first branchial arch, the hypobranchials are not attached to the basibranchial, but each is fastened to the posterior margin of the basihyal. Consequently, except in a dorsal view with the cranium removed, they are not easy to see, and the ceratobranchial appears as if it arose from the ceratobranchial of the second arch. Also the pharyngobranchials are joined together in the mid-dorsal line. Except for these departures, the arrangement of the cartilages is normal.

The second arch has already been traced.

The third and fourth arches have a similar arrangement to that of the second.

The fifth arch, however, lacks the hypobranchial cartilages, the ceratobranchials joining directly with the sides of the basibranchial. Also each pharyngobranchial is joined at its tip with that of the fourth arch.

Drawings.—The most instructive drawings are a ventral view and a dorso-lateral view.

Laboratory Notes.—Make notes on the differences in the various branchial arches and on the relation of the visceral skeleton to the cranium.

Additional Cartilages

In addition to the arches which you have already examined, there are in the dogfish certain additional cartilages which are usually lost in the preparation of the visceral skeleton, or if they have been preserved are found loose. These are the **labial cartilages**, of which there are two pairs and which are found in the angles of the mouth; and the **extra-branchial cartilages.** Of these latter there are three pairs found in relation with the second, third, and fourth branchial arches. They are slender rods of cartilage lying in the tissues on the outside of the arches concerned, and are again referred to later (page 106).

The Vertebral Column

The vertebral column consists of a large number of entirely cartilaginous **vertebrae** bound together by fibrous material, and to it are attached the muscles or myotomes of the body wall. Each vertebra is made up of three distinctive parts: (1) a cylindrical central portion, the **centrum** or body of the vertebra, upon which is (2) the **neural arch,** which encloses and protects the extension of the brain called the spinal cord, and (3) projecting from the lower part of the centrum, the paired **transverse**

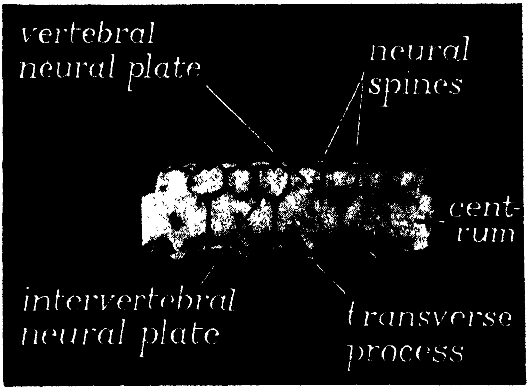


Fig. 6.—A piece of vertebral column from the trunk region.

processes, to which, in the trunk region only, ribs are attached. Each vertebra has been developed around and within, but not from, the embryonic axial stiffening rod, the notochord, which, as will be seen later, has not been entirely obliterated.

To obtain a clear conception of the constitution of a single vertebra, examine first a piece of vertebral column from the trunk region. It is well to have a piece which has been preserved in fluid and also a piece which has been dried. First of all orientate the specimen. This can be done by looking at the cut end, when the position of the

neural arch forming the spinal canal, which lies on the *dorsal* side of the centrum, can be distinguished at once. Now lay the " wet " specimen down on its side, in a dish of water, and examine the lateral surface with a lens. It is at once evident that the main portion of the column is divided into " segments," each of which is a vertebra, at the lower portion of which is a single piece of cartilage, the **centrum.** Note that the anterior and posterior limits of each centrum are marked by ridges. Adjacent ridges have a slight depression—more evident in the dry specimen, which should be examined for this point—between them.

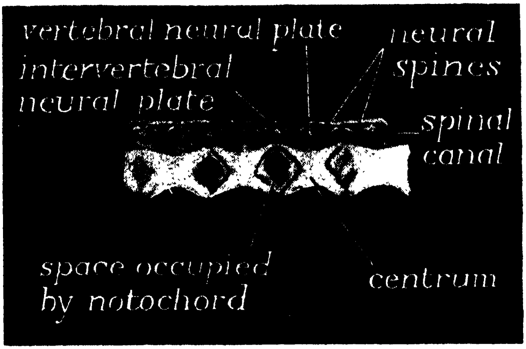


Fig. 7.—Sagittal section of the vertebral column in the trunk region.

It follows, therefore, that where the ridges of contiguous centra meet, a prominence will be formed, and if the summit of such a prominence is examined closely, the dividing line between the contiguous centra will be seen on it. In this way the extent of each centrum can be determined.

Dorsal to the centra lie the **neural arches,** which, it will now be seen, are composed of plates of cartilage fastened together. Consider first those plates in relation with individual centra. You will find that each centrum has arising from it a polygonal plate, the **basi-dorsal** or **vertebral neural plate.** These plates, however, are not contiguous,

but the interval between successive vertebral neural plates is filled by a separate plate, the **inter-dorsal** or **intervertebral neural plate.** It follows, therefore, that each centrum will have in relation with it on each side, two half intervertebral neural plates, one in front and one behind a vertebral neural plate. These plates form the sides of the neural arches, but the " keystone " of each arch is formed by two small median pieces of cartilage, rounded above, which fit into the spaces between the vertebral and intervertebral neural plates. These are the **supra-dorsals** or **neural spines.**

Projecting laterally from each side of each centrum is a truncated pyramid of cartilage, the **basi-ventral** or **transverse process,**[1] to each of which, in the trunk region, is attached a slender cartilaginous **rib.** The ribs are usually not present in the loose material used for class work, and to see them a mounted preparation of a whole skeleton should be examined.

It will now be clear that in the dogfish each vertebra consists of a single solid centrum surmounted by a neural arch composed of a vertebral neural plate with half an intervertebral before and behind, the arch being completed by two median neural spines, and, arising from each side of the centrum, a transverse process.

Now examine a piece of vertebral column which has been sectioned longitudinally in the mid-vertical line—a sagittal half as it is called. In the region of the centra, on the cut surface, a series of X or hour-glass-shaped structures will be seen. Each of these represents one centrum, which, it will now be obvious, is a cylindrical body concave in front and behind—*i.e.* **amphicoelous.** It follows from the shape of these centra that there will exist between consecutive centra a bi-convex space. This space, in the fresh column, would be found to be filled with gelatinous material, which

[1] These transverse processes, although having the same name, are not homologous developmentally with the transverse processes of the vertebrae of higher vertebrates. In these animals the transverse processes arise from the neural arch and not from the centrum. Consequently the ribs of the higher vertebrates are not homologous with those of the dogfish.

is the remains of the **notochord** which was not obliterated when the centra were being formed. If the section has passed exactly through the mid-vertical plane of the centra, you should be able to distinguish a fine canal in the narrow centre of each centrum by which the spaces between the centra (intercentral spaces) are connected with one another.

Above the centra is the **spinal canal,** the cavity enclosed by the neural arches, and in which lies the spinal cord.

Finally examine a piece of column from the caudal region to observe the modifications which have taken place in this region. Proceeding as you did with the piece from the trunk region, you will notice that the plates present in the neural arches are precisely the same as in the trunk region except that, if the piece is from the extreme posterior region of the tail, the neural spines are drawn out dorsally. Ventrally, however, the two pieces differ. The transverse processes or basi-ventrals, instead of projecting laterally, and having ribs attached to them, have grown down ventrally and meet in the middle line to form an arch—the **haemal arch**—below the centrum. In this arch lie the caudal artery and vein, to which, of course, it affords protection. As the end of the tail is approached, there is an increasing tendency for the ventral portion of the haemal arch to be pulled out either antero-posteriorly or ventrally to form **haemal spines.**

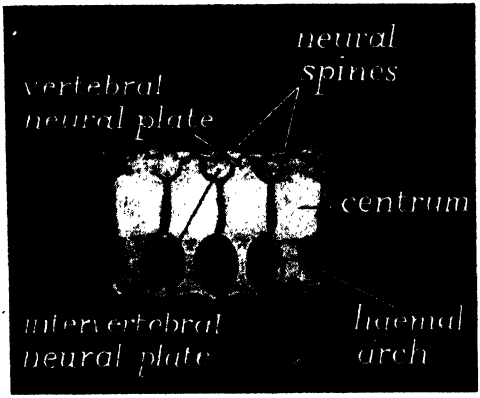


Fig. 8.—A piece of vertebral column from the tail region.

The existence of an arch both above and below the centrum sometimes causes difficulty in orientating the specimen; but this is soon overcome if it is remembered that to each centrum there are two neural spines but only one haemal spine. Hence observation of this point enables you to determine at once which is the dorsal side of the column. Also there are usually spaces between successive haemal arches which are not present in the neural arches.

Drawings.—Make drawings of the lateral view of two or three vertebrae both in the trunk and caudal regions, and of the end view of each. Also draw the cut surface of the sagittal half.

Laboratory Note.—Write a note on how to determine the dorsal and ventral surfaces in the extreme caudal region.

THE APPENDICULAR SKELETON

The appendicular skeleton consists of the pectoral girdle with the skeleton of the pectoral fins and the pelvic girdle with the skeleton of the pelvic fins.

The Pectoral Girdle

It is usual in the preparation of the pectoral girdle and fins to leave the skeleton of the fins attached to the girdle; but first examine the girdle, ignoring the skeleton of the fins for the present. In a complete mounted skeleton you will see that the pectoral girdle occupies a position in the anterior part of the body immediately behind the visceral skeleton. It consists of an inverted arch of cartilage which, in the living animal, is embedded in the muscles. It has no skeletal connection with the vertebral column, and lies almost vertically in the body-wall with a fin attached to each side.

Examining the girdle more closely, it will be seen that its base is broadened antero-posteriorly, and that each side tapers until the thin upper end is reached. There are no well defined regions in the girdle, but the point of attachment of the fin skeleton marks off an upper **scapular portion** from a lower **coracoid portion.** Each half of the girdle, then, consists of a dorso-lateral, slender, tapering,

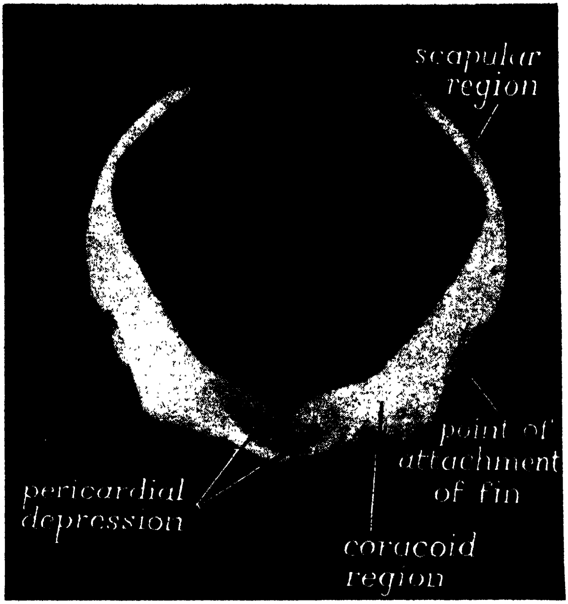


Fig. 9.—Anterior view of the pectoral girdle.

scapular region, and a ventral stouter, broader, coracoid region. The two halves are fused together in the mid-ventral line, and in this ventral region a broad depression facing antero-dorsally is to be seen on its upper surface. This is the pericardial depression in which the heart lies, and this portion of the girdle supports the floor of the pericardial cavity.

Examining the posterior face of the girdle, you will see that just where the thickened coracoid region passes into the scapular region, the cartilage projects in the form of a ridge inclined at an angle. It is to this ridge that the proximal portion of the fin skeleton is attached. Compare a girdle without fins with one to which the fins are still attached to confirm this point.

Drawing.—Draw the pectoral girdle from the anterior aspect to show the regions and the pericardial depression.

Laboratory Notes.—Make notes on the position of the girdle in the body, and the mode of attachment of the fins.

The Pectoral Fin Skeleton

The skeleton of each pectoral fin consists of two parts—the cartilaginous skeleton, which supports the " body " of the fin and to which the fin muscles are attached, and the dermal fin-ray skeleton, which supports the flexible periphery of the fin.

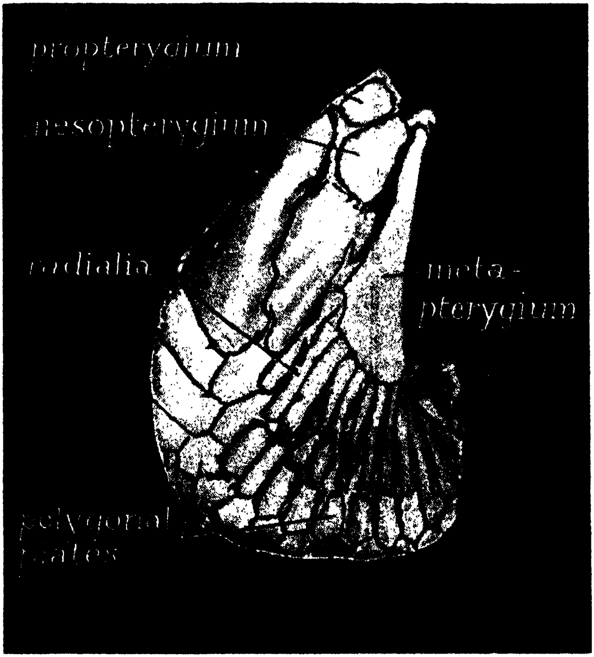


Fig. 10.—The cartilaginous skeleton of the left pectoral fin from above.

Consider the cartilaginous skeleton first. It consists of pieces of cartilage bound together by fibrous material. These cartilages can be divided into two series, the basal cartilages or **basalia**, which form the proximal portion of the fin skeleton by which the fin is attached to the girdle, and the radial cartilages or **radialia**, which support the main portion of the "body" of the fin. The basal cartilages are three in number; the **propterygium**, the **mesopterygium**, and the **metapterygium**. Examine now this region of the fin skeleton, and it will be seen that these three cartilages differ in size, the propterygium being the smallest and the metapterygium the largest. The shape of the individual cartilages can be best seen in a detached skeleton, though most of the features can be distinguished in one still attached to the girdle. All three pterygia are roughly triangular in shape, with their proximal ends somewhat truncated, and the mesopterygium overlaps the metapterygium on the lower face of the fin. These characters of the basal cartilages will enable you to determine whether a detached specimen that you may be examining belongs to the right or left side of the body. The fins are held almost horizontally, *i.e.* practically parallel to the upper and lower surfaces of the body of the animal, so that if the skeleton of the fin is placed with the narrow end—*i.e.* the point of attachment to the girdle—pointing away from you, and the surface on which the mesopterygium overlaps the metapterygium directed downwards, then the side on which the propterygium lies determines the side of the fish to which the fin belongs, since the propterygium is always on the outside.

Spreading out fanwise from the basal cartilages are a series of **radial cartilages.** The propterygium and the mesopterygium have each one radial—much stouter and broader than the others—in connection with them. The metapterygium, however, has several slender radials attached to it.

The periphery of the cartilaginous skeleton is completed by a number of polygonal cartilages or **polygonal plates.**

As was stated above, the margin of the fin is supported by **dermotrichia** or **horny fin-rays.** These, as their scientific name implies, are skin structures, and therefore belong strictly to the exoskeleton. Each horny fin-ray is

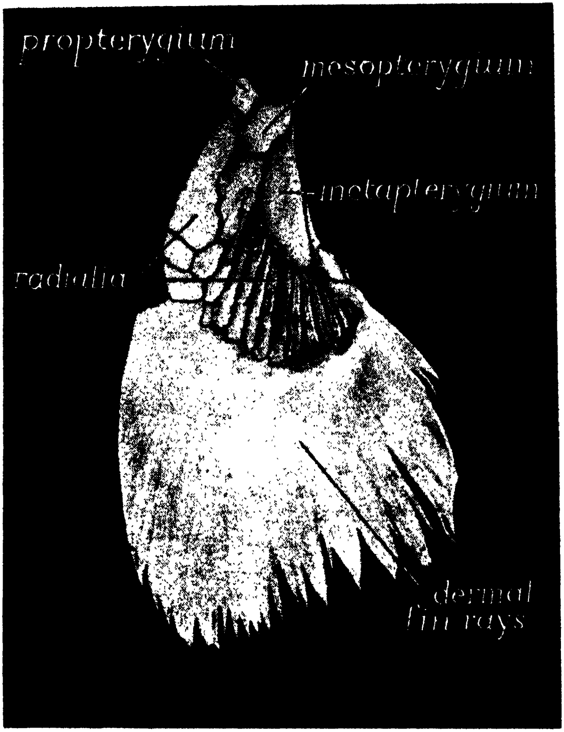


Fig. 11.—The cartilaginous skeleton and dermal fin-rays of the right pectoral fin from below.

a slender structure made of a material resembling horn, and is not broken up—as in the fin-rays of some other fishes—into portions or segments. There are two series present, one derived from the skin of the upper surface of the fin,

and the other from the lower. The proximal ends of the dermotrichia overlap the cartilaginous skeleton, one series on the upper and the other on the lower surface. Commonly the dermotrichia are removed during the preparation of the fin skeleton, and in order to see their relation to the cartilaginous skeleton, a museum preparation or a demonstration specimen should be examined. Alternatively, if a fin which has been soaked in water for several days is taken and the skin stripped off, the relations of the dermotrichia can be seen at once.

Drawings.—Make a drawing of (1) the cartilaginous skeleton of the fin from the dorsal surface, and (2) the three pterygia from the ventral surface to show the relations of the mesopterygium and metapterygium. Indicate in the same drawing the arrangement of the dermotrichia.

Laboratory Notes.—Make a note on the method of determining to which side of the body a specimen of a pectoral fin belongs, and also on the relation of the dermotrichia to the cartilaginous skeleton.

The Pelvic Girdle

The pelvic girdle in the dogfish is much simpler in form than the pectoral girdle. In the adult it consists of a simple, almost straight bar of cartilage embedded in the muscles of the ventral wall of the abdomen just in front of the cloaca. To it are attached the pelvic fins of which only a relatively small part of the periphery is free and movable. The girdle is consequently not connected in any way with the vertebral column, a point in which it differs from the condition in the higher vertebrates.

It is usual, in prepared specimens, as with the pectoral girdle and fin skeleton, to keep the fin skeleton attached to the pelvic girdle; but examine the girdle first. Viewed from the ventral surface, the girdle is a straight bar of cartilage, the ends of which are prolonged slightly forwards. Like the pectoral girdle, it is really composed of two halves which have fused together in the mid-ventral line. No definite regions are discernible, but in an attempt to correlate the parts of the girdle with those in the higher

vertebrates, the main portion stretching between the points of attachment of the two fins is sometimes called the ischio-pubic portion or **ischio-pubic bar.** Correspondingly, the small projections—which are directed somewhat

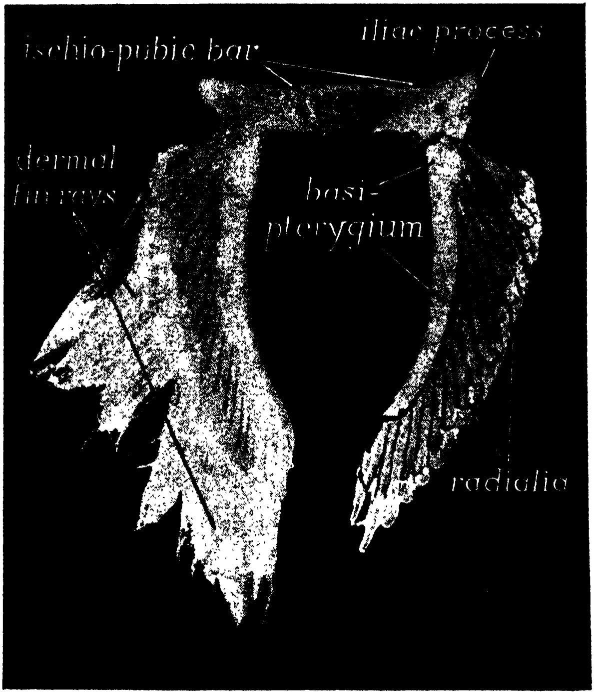


Fig. 12.—The pelvic girdle and fin skeleton (female) from below. The dermal fin rays have been removed from the left fin.

dorsalwards—at the ends of the girdle, and consequently dorsal to the points of attachment of the fins, are called the iliac portions or **iliac processes.** The fins are attached almost immovably to the girdle, and the surfaces of attachment are sometimes called the **acetabular surfaces.**

The Pelvic Fin Skeleton

As with the pectoral fins, the skeleton of the pelvic fins consists of a cartilaginous portion, and a peripheral

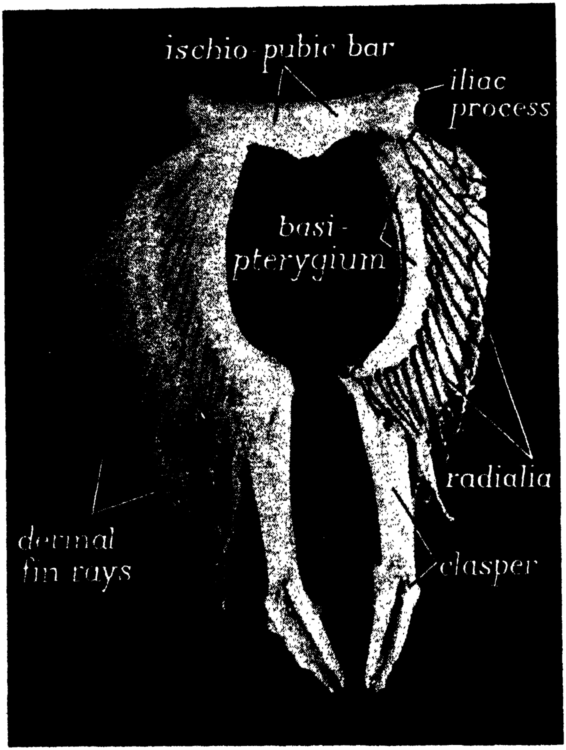


Fig. 13.—The pelvic girdle and fin skeleton (male) from above. The dermal fin-rays have been removed from the right fin.

portion of dermotrichia. The cartilaginous portion is much simpler than that of the pectoral fins, though in essentials it is based on the same plan. It is made up of a basal portion by which it is attached to the girdle, and a

series of radial cartilages. The basal portion consists of a single cartilage, the **basipterygium**, long, slender, and attached at its proximal end to the acetabular surface of the pelvic girdle. Attached to the outer side of the basipterygium is a series of slender **radial cartilages.**

The dermotrichia which form the margins of the fin skeleton are arranged in an upper and lower series, and partly overlap the cartilaginous skeleton.

As will be seen when the external characters are examined, the condition of the pelvic fins differs in the two sexes. In the female, the condition of the skeleton is that already described above, but in the male there is, arising from the distal end of the basipterygium, the skeletal support of the intromittent organ or **clasper.** This is a cartilaginous tube, the wall of which is fashioned like a C-spring with the narrow opening on the dorsal side of the tube. At the free extremity the sides of the tube are more separated.

Drawings.—Make drawings of the pelvic girdle and fin skeleton of both sexes.

Laboratory Note.—Make a note on the relation between the cartilaginous fin skeleton and the dermotrichia.

Median Fins.

The skeleton of the dorsal and ventral median fins consists of a series of slender radials, to the distal ends of which are attached the dermotrichia or horny fin-rays of both sides of the fins. The radials are embedded between the right and left segmental muscles above the vertebral column. In the dorsal lobe of the caudal fin the dermotrichia are attached to short and comparatively wide radials which are in contact with one another, and, except for a few anterior ones, with the neural spines. Ventrally, the fin-rays are attached to contiguous hypurals, which appear to be a combination of haemal spines and radials.

EXTERNAL FEATURES

Various regions of the body are frequently referred to by descriptive terms with which you need to be acquainted. The **cephalic region** refers to the head; the **branchial region** is that part occupied by the respiratory organs or gills; the **pectoral region** is that part which houses the part of the skeleton (the pectoral girdle) to which the fore limbs are attached, and which corresponds to the chest region of higher vertebrates; the **pelvic region** is the corresponding area round the hind limbs where the pelvic skeleton is found; on the ventral side, between the pectoral and pelvic regions is the **abdominal region**; the **caudal region** is the tail which extends backwards beyond the pelvic region.

Form of the Body

The form of the body is associated with the habitat of the fish, *i.e.* the shape is adapted to an aquatic life. Note (1) the graceful, streamline form, with no rigid projections like shoulders to interfere with progress through the water; (2) the tapering of the body at both ends, more gradual behind than in front, the widest part being at the level of the fore limbs; (3) the flattened or dorso-ventrally compressed shape of the head, eminently suited to progression through the water.

The body may be said to be composed of three parts, (1) the head; (2) the trunk; and (3) the tail. The **head** is usually regarded as that part from the snout to the last gill cleft, though some authors prefer that the spiracle should be regarded as the posterior limit. In most vertebrates the head is limited posteriorly by the hind border of the skull, but in the dogfish the pharynx is relatively more extensive than in other vertebrates, and reaches back much farther than the hinder margin of the cranium, and is supported by the visceral arches, which, strictly speaking, form part of the skull. The chondrocranium extends backward actually only a short distance

beyond the eyes. The **tail** or caudal region is that part posterior to the vent at the base of the hind paired fins, and the **trunk** is the intermediate portion.

The Skin

In **coloration** the dogfish, like other fishes, is darker above than below. As seen from above, the ground colour is a brownish grey upon which are spots of a much darker tone. The spots on the back are small and close together; at the sides they become larger and more widely separated. On the fins, the spots are large and comparatively few; the ventral median fin has no markings. From a ventral aspect the fish is pale in colour throughout.

The skin of animals is most generally provided with some form of protection; there may be slime only, or there may be a covering of hair, feathers, or scales. Fishes are usually provided with an exoskeleton or covering of scales, but unlike those of bony fishes like the herring, those of the dogfish are of a type characteristic of the more primitive fishes—the cartilaginous fishes or Elasmobranchii—and are known as **placoid scales or dermal denticles.**

Pass your fingers along the surface of the body from the head backwards; then pass them in the opposite direction. In the backward direction the surface feels quite smooth, but in the other, it feels like a file. As a matter of fact the cured skin of the dogfish and its relatives is used for polishing and for covers of handles to assist gripping; commercially it is known as shagreen.

Next examine the skin with a lens, and you will see the cause of the roughness in one direction and smoothness in the other. You will notice an armour of finely pointed spines directed backwards. But you cannot see the anchorage of the spines; this is a plate embedded in the dermis of the skin in which the scales have been formed. The scales are therefore called dermal scales or denticles. You will read in your textbook that these scales have the structural characters of teeth, and they may therefore best be called dermal denticles. The plate is calcified; some authorities state that it consists of bone, while others say

it is made of cement, which is a bony tissue, and if this is so, it is the only example of bone found in the body of the dogfish. However, since there do not appear to be any Haversian canal systems present, it is probably wiser to avoid reference to *true* bone in these scales. The spine is made of dentine covered with enamel; moreover, the spine has a pulp cavity containing blood vessels which pass through a hole in the basal plate.

Not only do these scales resemble teeth in structure, but at the mouth they function as teeth. Examine the mouth, and you will see that the skin over the jaws has **teeth** which closely resemble the scales. (See Fig. 14.) These teeth are not confined to a single row—there are three or four rows—and you will notice that the direction of the spines is towards the mouth cavity. These teeth are not for biting, for you will notice that they are not opposed, *i.e.* the teeth in the two jaws do not come into contact as the mouth is shut. Those in the lower jaw make contact with a sort of cushion behind the teeth of the upper jaw. It is clear, therefore, that the use of these teeth is to prevent the escape of prey once seized. Put your finger into the mouth and see how difficult it is to withdraw it; you will find it necessary to open the jaws in order to get the finger out. A study of the dermal denticles, therefore, provides us with an interesting comparison with the teeth in higher animals. Later you will examine them under the microscope.

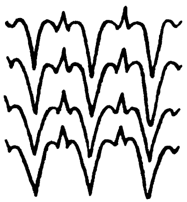


Fig. 14.—Teeth as seen through a lens.

Laboratory Note.—Write a short note on the dermal denticles as you have observed them, both on the general surface and on the jaws.

Fins

Outgrowths of the body into which true skeletal elements enter as supports are characteristic of vertebrates, and the fins of the dogfish are such outgrowths, but with a peculiar

type of skeleton, the plan of which is a feature of fishes in general. You will notice two kinds of fins, one paired and the other kind, in the mid-dorsal and mid-ventral line of the caudal region, unpaired. All are directed backwards, an advantage for forward movement.

UNPAIRED FINS. The unpaired or **median fins,** seen only in a complete specimen, include two dorsal fins, the caudal fin, and the ventral median or anal fin. The **dorsal fins** are named from their positions, (*a*) anterior or first dorsal fin; and (*b*) posterior or second dorsal fin. Note their positions and relative sizes. Being vertical in position and capable of movement from side to side, these fins will function as steering and balancing organs.

The **caudal fin** extends round the end of the tail from the posterior dorsal fin to about an equal distance along the ventral median line. Notice the shape of this fin together with the upwardly tilted extremity of the body. The extent of the upturning is but slight and scarcely recognisable in the limp, dead fish. There is a greater development of the fin ventrally than dorsally; the upper portion is more regular than the lower which is partially subdivided. The tail is the propulsive organ of the fish, and is used as a scull is used from the stern of a rowing boat, producing a sinuous movement forwards. In nearly all fishes the ventral lobe is larger than the dorsal, and in a great many "food" fishes with tails apparently symmetrical, dissection proves that the fin is really almost entirely ventral lobe only. The dogfish type of caudal fin is known as **heterocercal**, and is characteristic of the *Elasmobranchii.*

[The caudal fins of such fishes as the herring, mackerel, cod, and eel, in spite of external appearances, are externally symmetrical but internally morphologically unsymmetrical, the ventral elements of the skeleton preponderating. Such fins are said to be homocercal. In the early larval stage of all fishes, the caudal fin is diphycercal, *i.e.* symmetrical both externally and internally. The original ancestral caudal fin which was symmetrical externally and internally is referred to as protocercal.]

Examine a specimen of a common food fish (a Teleost) for a comparison of the caudal fin with that of the dogfish.

The **ventral median fin,** sometimes rather inappropriately called the anal fin, is placed almost immediately below the space between the two dorsal fins and in the mid-ventral line. This fin must also be regarded as designed for steering or steadying the animal.

PAIRED FINS.—These fins correspond to the fore and hind limbs of other animals. Their relative positions are of importance. The less specialised fishes have the hind pair, the **pelvic fins** (or ventral fins of some authors—an unfortunate term liable to lead to confusion)—well back along the body, *i.e.* abdominal in position; the highly specialised fishes usually have the pelvic fins about level with the anterior pair, the **pectoral fins,** *i.e.* thoracic in position; or indeed they may be actually anterior to the pectorals, or jugular in position. Look for the position of the pelvic fins in specimens in a museum or in a fishmonger's shop.

The Pectoral Fins. The pectoral fins are large and project more or less horizontally from the sides of the body at its broadest part, and are capable of being folded back. Notice that the free edge is flexible as compared with the rest of the fin. If you watch a dogfish swimming in an aquarium you will realise the importance of the pectoral fins to the fish as elevating organs and, to some extent, as balancing organs, for the anterior edge has a slight upward tendency. By these fins the fish can also rapidly slow down its movement.

Examine in a general way the skeleton of the pectoral fin. The elements you see make it quite clear why the body of the fin is fairly rigid and the fringe flexible; the cartilaginous pieces give firmness and the horny rays flexibility. You can now easily note the areas shown in the fin which are occupied by cartilages and horny rays.

[The rays fringing the fins of fishes are called *dermotrichia,* and the dermotrichia found in the dogfish are of the kind known as *ceratotrichia.* The name *actinotrichia* is usually applied to those of

larval fishes and those sometimes found at the edge of the fins of other fishes.]

The museum preparation of the skeleton will show that the fin skeleton is firmly attached to a cartilaginous arch or pectoral girdle.

Examine the pectoral fins of your specimen, and notice carefully how you would be able to identify each as right or left if it were detached from the body.

The Pelvic Fins. The pelvic fins should be compared with the pectorals in respect of their (*a*) size and shape; (*b*) attachment to the body; and (*c*) mobility. Their basal skeletal elements are attached to a bar of cartilage, the pelvic girdle, and you should locate this girdle by feeling for it between the fins. With the pelvic fins is revealed a sexual difference; while in the female the fins are simple in outline, in the male the inner edge of each fin joins the other, and a grooved rod-like structure is seen running backwards on the ventral side of each fin. These are the **claspers** by which the male reproductive cells are transferred to the oviduct of the female. Pass your finger along the clasper, and note that the spines of the dermal denticles point forwards, in the opposite direction to those on the general body surface. This is a device to prevent slipping when inserted into the oviduct. Claspers are characteristic of the males of the cartilaginous fishes.

Claspers. Examine the claspers in more detail. Holding the end of one clasper, turn it outwards at a right angle so as to expose the dorsal side. You will see that there is a longitudinal flap covering the groove. The flap itself is soft, but the sides of the groove are separated only with difficulty, except at the end of the clasper. At about the middle of the clasper, make a clean transverse cut across, and from the section you will see the reason for resistance to attempts to open the groove. The clasper is supported by a cartilage, tubular in form when closed, and in transverse section like a C-spring; thus the groove is of the nature of a duct. (See Fig. 23.) This duct is in continuation,

forwards, with a sac-like structure situated just beneath the skin.

Drawings.—1. Draw an outline of the complete fish in side view, correct in proportions, and indicate the positions of the various fins.

2. From a complete specimen, draw a figure of the caudal fin, labelling it "heterocercal type of caudal fin," and indicate the course of the vertebral column in the fin.

3. Draw the ventral view of the pelvic fins with that section of the body (the pelvic region) to which they are attached, both of the male and of the female, to indicate the difference in the sexes. Indicate also the position of the dermotrichia.

4. Draw a diagram of the pectoral fin, either right or left, and label it as such. Indicate the areas of the dermotrichia, and the basal cartilaginous supports.

Laboratory Notes.—1. Write a note on the function of each of the fins.

2. Write a short note defining each type of caudal fin—protocercal, diphycercal, heterocercal, and homocercal.

Apertures

The **mouth**, crescentic in form, is not terminal, but on the under side of the head a little distance from the anterior end. This position, which is characteristic of the cartilaginous fishes (*Elasmobranchii*), may be associated with the habits of the dogfish which is principally a bottom feeder. You have already noticed the teeth and the direction of their spines. You will realise, of course, that the mouth serves a double purpose; not only is it an aperture for the intake of food, but also for the taking in of water for respiration. Water passes in through the mouth and out at the gill slits, and does not enter the digestive tract, which remains closed except when swallowing food.

The nasal apertures or **nostrils** are paired and placed ventrally in front of the mouth and near the margin of the head. The ventral position of the nostrils is a feature of the Elasmobranchs, and in a few cases only are the nostrils dorsal. They are connected with the mouth externally by grooves called the **oronasal grooves,** each of which is covered by a loose flap. These grooves are a feature which

is present only in the embryonic condition in higher vertebrates, and they therefore have a special interest and show a primitive condition. The nasal apertures lead only to a pit—the **nasal pit**—containing folds on which are the olfactory sensory cells. (See Fig. 15.) Lift up the flap and notice the groove and the interior of the pit. Next cut away the flap on one side so as to obtain an uninterrupted view of the interior and of the sensory folds. In most animals the nostrils are not only olfactory but respiratory too. In the dogfish, however, they are clearly only olfactory in function, and serve no respiratory purpose. There is no connection with the interior of the mouth.

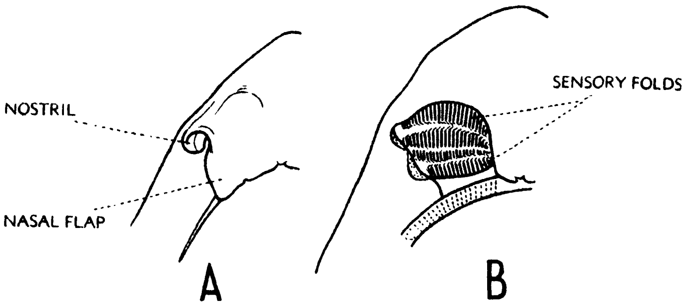


Fig. 15.—Nasal pit. A, entire; B, flap removed.

The absence of internal nostrils is a feature characteristic of fishes; the small class of lung fishes is the only exception.

The sense of smell is strongly marked in the dogfish, and the animal depends chiefly on this sense in its pursuit of food.

Drawings.—1. Make a drawing of the under side of the head so as to show the mouth, the nostrils, and the oronasal groove. Get the proportions as correct as possible so that the distance from the mouth to the anterior end, and that of the nasal pits from the side of the head, are made clear.

2. Make a sketch to show the olfactory sensory folds in the nasal pit.

The **gill slits** are five in number on each side of the pharynx. They are respiratory apertures, each placing a gill pouch in communication with the outside water. In the living fish the water can be seen going in at the mouth and out at the gill slits. It is important to notice the difference between the gill pouch openings in the dogfish and the bony fishes (Teleostei); each gill pouch has a separate opening on the exterior in the Elasmobranchii—a primitive feature—while in the Teleost there is a gill cover at the hind end of which is the single opening to the exterior. Examine a Teleostean fish (herring, trout, mackerel, etc.) for this point. Pass a seeker through any of the gill slits of the dogfish, and notice particularly the slanting direction of each gill pouch, the external opening being posterior to the internal, so that the water current can freely pass from the pharynx to the exterior. Look inside the gill slits and notice the gill lamellae on the walls of the pouches.

The **spiracle,** which is a reduced gill slit, is a circular aperture just behind the eye. Look inside the spiracle and you will find on the anterior wall the lamellae of the reduced gill, about seven of them, which constitute the "false gill" or **pseudobranch.** The gill lamellae are a bright red in fresh specimens, but after preservation they lose their bright colour and are more difficult to recognise. Pass a seeker through the spiracle from the outside and note the angle of the passage as compared with that of the gill slits. It is obvious that the function of the spiracle is different from that of the gill slits. The fact is, when the mouth is closed, a current of water passes *in* at the spiracle, which thus, in *function,* resembles the nostril in higher types. It is most important, however, to remember that it is merely a functional resemblance, for morphologically the spiracle is represented by the passage between the middle ear and the pharynx in higher animals. This may be regarded as an example of analogy and not homology, for the spiracle is homologous with the passage referred to in higher types; in the dogfish there is a diverticulum from the spiracle which reaches to the auditory capsule.

Drawing.—Make a drawing of the side view of the head, labelling the position of the mouth, the eye, the spiracle, gill clefts (numbered from the front), and the pectoral fin.

Laboratory Note.—Write a note on the direction of the water current through the gill pouches and the spiracle, and on the presence of a pseudobranch in the spiracle.

THE APERTURES OF THE SENSORY MUCOUS CANALS. The small circular apertures of this remarkable sensory system are found in many places on the head, *e.g.* between the mouth and snout, in front of and behind the nostrils, along the side of the head, backward from the angle of the mouth, behind the eye and over the snout. After drying the side of the head with a duster, squeeze the skin with the fingers, when little beads of mucus will exude through the apertures, thus disclosing their distribution. You cannot expect this rough method to determine the exact course of the series of mucous canals, but it will convince you of their presence. Those pores on the snout are the openings of tubes filled with mucus, the tubes ending under the skin in nodular masses or ampullae, known as **ampullae of Lorenzini.** Above and below the eye, the pores communicate with longitudinal tubes which unite behind the eye to form one canal along each side of the fish with communications to the exterior by pores. The position of this lateral canal is marked by a slight groove called the **lateral line.** If the tail is cut off, at the cut end of the body you can see the tube underlying the lateral line in transverse section. It is found just a little above a fairly prominent blood vessel—the lateral cutaneous vein.

This sensory system, which together with the membranous labyrinth of the ear collectively called the **neuromast organs** or **acustico-lateral organs,** is peculiar to fishes and a few other aquatic animals, *e.g.* the tadpole of the frog. It is evidently a system associated with aquatic life, and it is morphologically related to the ear. Its function is said to be the detection of very low frequency vibrations, so that any disturbance in the water nearby is at once appreciated by the fish—a useful addition to the sensory system in the comparative or complete darkness of deep water.

The **ductus endolymphaticus** or **aqueductus vestibuli** communicates with the exterior, but it is impossible to locate the aperture without dissection. There are a pair of these apertures which are found on the top of the skull near the middle line at about the level of the spiracles. Each communicates with the ductus endolymphaticus of the internal ear. This external communication of the internal ear is a primitive character and a remnant of the original invagination by which the internal ear is formed in the embryo. In higher animals the communication is cut off at an early stage. If, as is usual, external pressure fails to reveal the openings by the exudation of mucus, a slight dissection involving the removal of a portion of the skin as shown in Fig. 16 will reveal the openings.

DUCTUS ENDOLYMPHATICUS

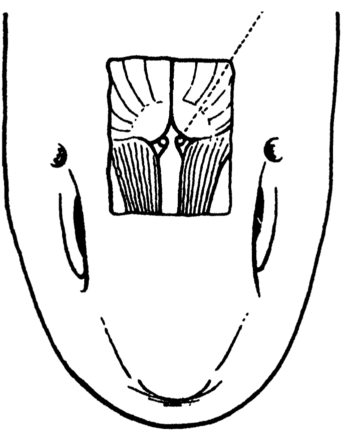


Fig. 16.—Aperture of the ductus endolymphaticus exposed.

Drawing.—In your drawing of the complete fish, insert the position of the lateral line and the courses of such mucous canals as you have been able to determine.

THE CLOACAL APERTURE. Lay the fish on its back, and look between the bases of the pelvic fins. You will see a groove—the **cloacal groove**—at the anterior end of which is an aperture, the **cloacal aperture,** into which a seeker can be passed. There is only a single aperture for the ejection of waste matter. By separating the pelvic fins as widely as possible and by looking into the cloaca, a median papilla is just visible. In the female (Fig. 17) this is the **urinary papilla,** and in the male (Fig. 18) it is the **urinogenital papilla**; in the case of the female, the papilla carries a duct which comes only from

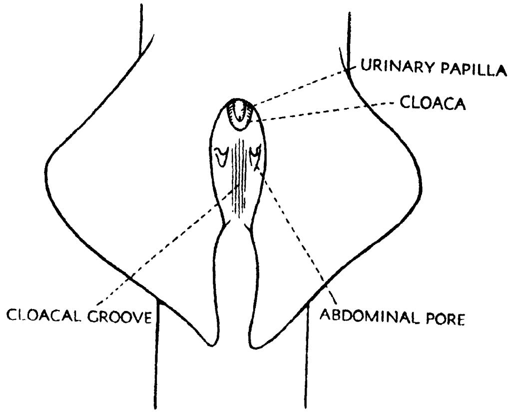


Fig. 17.—Cloacal region of a female dogfish. The pelvic fins pulled apart.

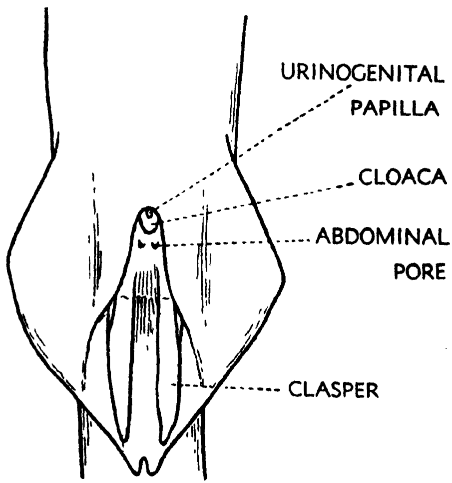


Fig. 18.—Cloacal region of a male dogfish. The pelvic fins pulled apart.

the urinary or kidney system, but in the male, both the waste matter from the kidneys and the sex cells from the generative organs are expelled from the apex of the papilla.

THE ABDOMINAL PORES. On each side of the cloacal groove, about half an inch ($1\frac{1}{4}$ cm.) from the cloacal aperture, is a slight depression, sometimes referred to as the **cloacal pouch**, in which is an aperture covered by a valve-like flap. These are the **abdominal pores** by which communication is established between the body cavity and the exterior. In fresh specimens a reddish fluid will most probably readily exude from the pores. In preserved specimens where the body wall has been partly removed, a seeker may be passed from the hinder part of the body cavity in the direction of the pore from which it will be seen to emerge. The seeker may also be passed from the exterior through the pore to the body cavity, but it is not so easy; however, by patient insinuation of the seeker past a valve-like projection, without forcing, the passage will be discovered.

The Eye

Notice the slit-like **eye.** The upper lid is not movable, but the lower eyelid can be brought upwards to cover the eye. The whole of the black area seen between the eyelids is **iris.** The " white " of the eye, or **sclerotic coat,** is scarcely, if at all, to be seen bordering the iris. Across the centre of the iris is the **pupil,** a dumb-bell-shaped slit with, at least in fresh specimens, a fringe of gold-coloured pigment.

Drawing.—Make a drawing of the pelvic region both in the male and female fish, so as to show all the parts visible in that region.

Laboratory Note.—Write down a list of all those external characters which may be regarded as adaptations to aquatic life.

GENERAL DISSECTION

THE BODY WALL

Dissection on a Fresh Specimen

The dissection now to be dealt with can be done on a fresh specimen only, since the parts to be described will most probably have been removed in preserved specimens.

Fix the fish dorsal side down on the dissecting board with an awl through the basal cartilages of each pectoral fin. It is useless to pin down the animal through the horny rays of the fin. You are advised to pierce the fin independently first, and to keep the fin well raised from the board after fixing the awl in the board; this avoids stretching the animal too tightly across the pectoral region.

Pinch up the skin with the fingers at about the middle of the abdomen, and make a small cut, in the skin only, with large scissors in the middle line. Inserting the blade of the scissors into this incision, cut forwards in the exact middle line *through the skin only* to a position well in front of the pectoral girdle, which can be felt as a hard band passing across the body between the fins. Reversing the position of the fish, continue the incision backward, again being careful, especially in the male, to cut only the skin, as far back as the pelvic girdle, which is also easily located by feel. Taking the edge of the cut in the large forceps, raise it and, using the back of a scalpel, separate the skin only from the underlying muscles. The operation involves the breaking down of a white filmy material, connective tissue, which binds the skin to the muscle beneath it. As you do this, examine the under side of the skin and make sure that you have removed no muscle with it. Clear the skin from practically the whole of the abdomen and round the pectoral girdle as shown in Fig. 19. Then cut off the flaps of skin. On one side clear the skin away from the base of the pectoral fin and neighbouring body wall, so as to expose clearly the muscles of the fin.

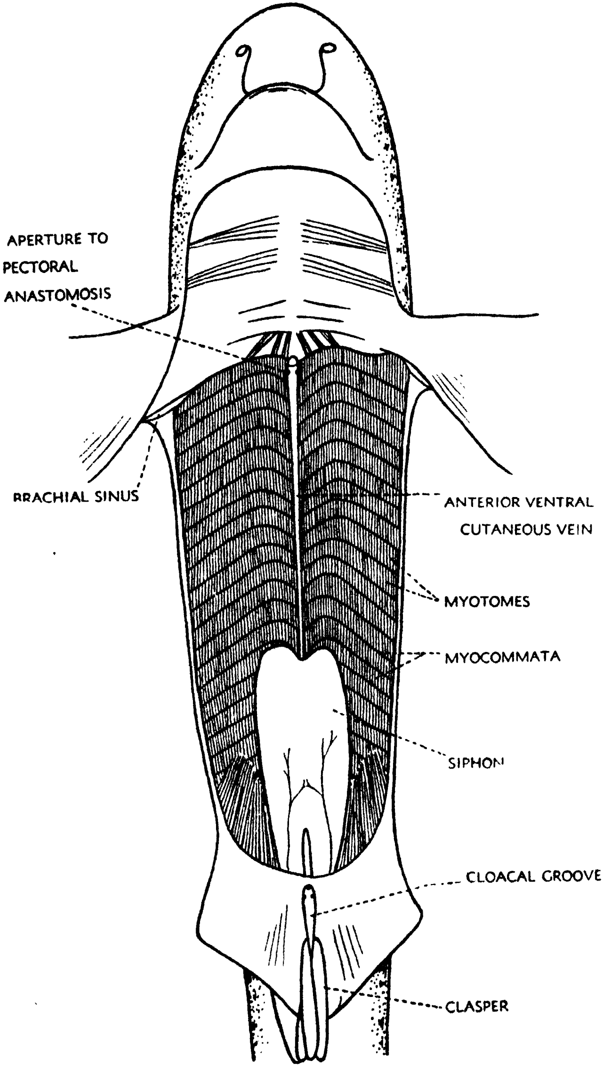


Fig. 19.—Male dogfish after removal of the skin from the ventral surface.

On the abdomen you will immediately recognise that the muscles of the body are arranged in segments or **myotomes** (**myomeres**) separated by connective tissue partitions or **myocommata.** Though not so obvious in the anterior region of the abdomen, posteriorly, just before reaching the middle line, the myocommata take a sharp bend backward. It is interesting to note that in animals higher in the scale than fishes, the myotomes rarely persist as such.

You have an excellent opportunity, which will not be available after opening the body cavity, to study the veins draining the deoxygenated blood from the myotomes of the ventral body wall. Along each myocomma you will see a vein to which pass numerous small veins from the longitudinally disposed bundles of muscle fibres; in fact the muscle bundles are indicated by the veins. The veins along the myocommata pass into a median vessel which you may possibly have cut open in places when removing the skin; but where it has not been opened you will observe the movement of the blood contained. This median vessel—the **anterior ventral cutaneous vein**—widens and becomes sinus-like as it approaches the region of the pectoral girdle, and if this part be opened, you will find at its anterior termination close to the girdle, two apertures, one on each side, by which it communicates with a transverse vessel or **pectoral anastomosis** along the posterior edge of the pectoral girdle.

Drawing.—Make a drawing of the ventral body wall with the skin removed, to show the myotomes and the anterior ventral cutaneous vein with its tributaries from the myotomes.

Dissection on a Fresh or Preserved Specimen

Remove the skin from the side of the body from a place a little anterior to the pelvic fin to the beginning of the first dorsal fin, as shown in Fig. 20, extending beyond the mid-dorsal line. You will now be able to appreciate the fact that the muscles of the body are arranged in a series of segments separated by partitions of connective tissue. The segments are called **myotomes** or **myomeres**, and the

partitions **myocommata.** The courses of the myocommata at once demonstrate that the myotomes take a zigzag course and do not form plane discs. The myocommata have five sharp bends, four only of which are seen in a lateral view, the fifth being ventral, as shown in a fresh specimen where no part of the body wall has been removed (see Figs. 19 and 20).

In the tail region, *i.e.* posterior to the cloaca, the myotomes above the lateral line alternate with those below, while in the trunk region they coincide with one another.

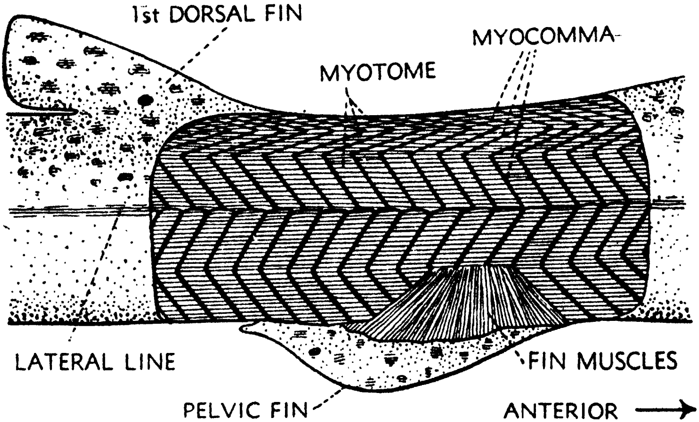


Fig. 20.—Body wall musculature in the pelvic region. Lateral view.

The probable explanation of this is that the tail is a propulsive organ which moves from side to side, and the alternate arrangement assists in the more vigorous movement of the caudal region. You can also observe the arrangement of the muscles of the pelvic fin.

This repetition of similar segments of muscle is an illustration of metamerism or metameric segmentation, a characteristic which the vertebrata share with many of the higher forms of invertebrata.

At the lateral line, you will observe that the myotomes are divisible into a dorsal and ventral part. In a section

across the body (see Fig. 60) it will be seen that these two parts are separated by a septum. In this septum lie the true dorsal ribs arising from the vertebrae.

Drawing.—Make a sketch of the myotomes of the pelvic region as shown in a side view.

THE DERMAL DENTICLES

These structures embedded in the skin have already been noticed in a general way, and you now have an opportunity to examine them in detail. Take three samples of skin, each about $\frac{1}{4}$ inch (or $\frac{3}{4}$ cm.) square, one from the ventral body wall, one from the dorsal body wall, and one from the jaw to include teeth. Treat each sample separately so that the three kinds of denticles shall not get mixed. Put the sample in a test-tube containing 1 or 2 per cent. caustic potash solution[1] to a depth of about an inch (2·5 cm.), and boil gently over a *small* flame. Hold the test-tube with a holder of some sort—a folded piece of paper will do—with the mouth directed away from you and other people, and preferably over a sink. Watch it carefully all the time, keeping it in continual movement by rapidly passing it in and out of the flame. Boil the skin until it has disintegrated; then fill up with water and allow the residue to settle before decanting off the liquid. Repeat until the liquid is quite clear. [If a large quantity of denticles is required, a larger piece of skin may be boiled in a beaker resting on a sheet of gauze with an asbestos centre.] With your thumb over the mouth of the test-tube, invert it and empty the contents into a watch-glass, and examine under the low power of the microscope. Or if desired, with a pipette, take a small quantity of the material and put it on a slide; drain off the excess water, cover the residue with a drop of glycerine or water, and examine under the low power of the microscope.

[1] A 10 per cent. solution is sometimes recommended, but such a strong solution is apt to boil far too vigorously and shoot out the whole contents of the tube. Again, some people assert that boiling in water is sufficient to dislodge the scales.

The denticles (Fig. 21) consist of a **basal plate,** which is embedded in the skin, and a **spine,** which is directed backwards, arising from the basal plate. You will probably see complete specimens and also specimens of basal plate or spine only. The incomplete ones have either been broken or worn, and it is interesting to remember that worn specimens are replaced by new scales produced between the original ones. To allow for this, the basal plates do not overlap, but are separated by a space.

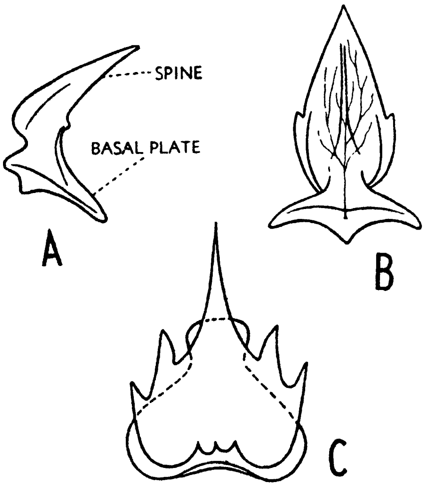


Fig. 21.—Isolated dermal denticles. A, from the dorsal surface, side view; B, the same in face view; C, tooth, face view.

Select a complete specimen. It is not likely that you will find one standing in its natural position, on its basal plate, for the spine makes the scale top-heavy. You will find some lying on their sides and others with the basal plate uppermost. The shape of the spine will differ according to the place from which it was taken. The denticles from the ventral surface will show a spine with a single point and smooth sides. Those from the dorsal surface will show, in addition to the terminal point, two lateral spikes, one on each side. In each case the basal plate is rhomboidal and concave on the under side.

The **pulp cavity** with branches can be seen in the spine, and the entrance to it is frequently plainly shown in the basal plate.

In the case of the teeth, the spine is modified and enlarged for the retention of food seized. Each tooth consists of a strong median spike and four laterals, two on each side, all definitely tooth-like in form. The basal plate is more or less triangular or rather trilobate.

You will thus see that the dermal denticles present a series from the plain simple spine to the five-pointed tooth. It would be an interesting exercise to examine scales from every part of the skin and to try to account for the differences found. A microscopical preparation of a longitudinal section of the skin, if available, would be useful to demonstrate the extent to which the dermal denticle projects above the surface.

Drawings.—Make a sketch of each of the kinds of dermal denticle you have found. A figure of the side view will show the direction of the spine in relation to the basal plate, and a face view will show the form of the spine and the pulp cavity.

Laboratory Note.—Make a note on the structural resemblance between the spines and the teeth of vertebrates.

SUPERFICIAL BLOOD VESSELS IN THE PECTORAL REGION

Dissection on a Fresh Specimen

Before opening the body cavity, it would be as well to pursue further the course of the pectoral anastomosis and its associated blood vessels. You have already seen the apertures by which the anterior ventral cutaneous vein communicates with the anastomosis. (See Fig. 19.) By inserting a blade of the fine scissors into the aperture on one side, open up the pectoral anastomosis, and you will find at a distance of only $\frac{3}{8}$ inch or $\frac{1}{2}$ cm. that a vein joins it from the abdominal wall. (See Fig. 22.) This is the **lateral abdominal vein,** sometimes spoken of as the deep lateral vein, but which is here relatively superficial; however, as you will observe later, the greater part of this vessel is deep seated—hence the alternative name—and will be found to pass along the inner side of the ventral body wall. A seeker

may be passed into it. Open the pectoral anastomosis a little further, and you will see that it is joined by the **brachial sinus** from the pectoral fin. With the back of a scalpel,

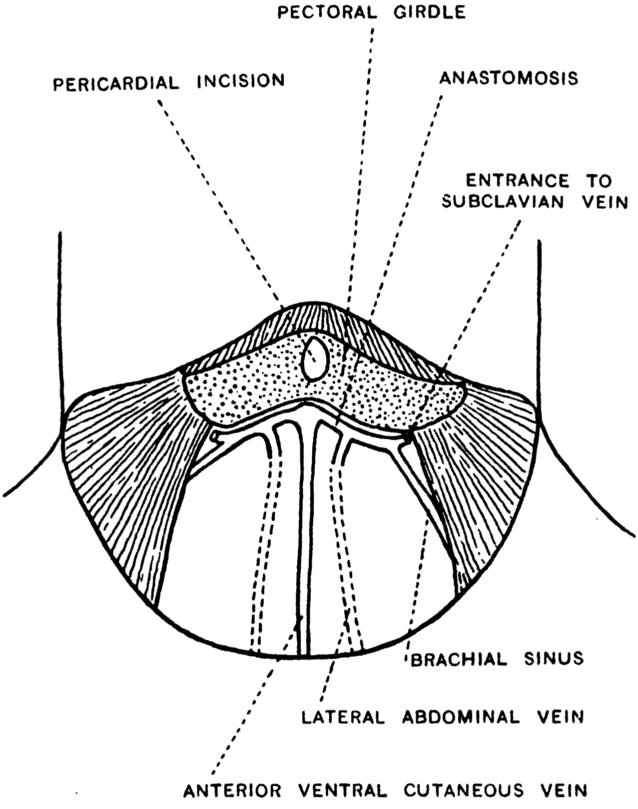


Fig. 22.—Superficial blood vessels in pectoral region.

break down the connective tissue between the fin muscles and the body wall, and you will see the sinus along the inner edge of the fin. Insert a seeker into the sinus.

Close to the entrance of the brachial sinus into the pectoral anastomosis is a large aperture. This is the beginning of the **subclavian vein,** which thus collects blood from the brachial sinus, the lateral abdominal vein and the anterior ventral cutaneous vein before discharging it into the Cuvierian sinus, which you will study later. An inserted seeker will show that the subclavian vein takes a dorsal course.

A variation in the courses of these vessels may be met with; for example, sometimes the brachial sinus and lateral abdominal vein join the pectoral anastomosis at the same point.

Drawing.—Inside an outline of the pectoral region of the body make a drawing of the course of the blood vessels you have just traced, fully labelling each vessel.

Dissection on a Preserved Specimen

In preserved specimens, a portion of the body wall in most cases has been removed, and the pectoral girdle has been cut in order that preservative may be admitted freely to the viscera and the heart. In such cases the anterior ventral cutaneous vein will have been destroyed, and the transverse pectoral anastomosis along the posterior border of the pectoral girdle will have been cut through. By examining the cut surface of the pectoral girdle, you may be able to find the cut end of this vessel (the pectoral anastomosis) and can then proceed as directed for the dissection on a fresh specimen. When, however, you come to the lateral abdominal vein, if the body wall has been cut away, a seeker inserted into the vein from the anastomosis will soon appear at the cut edge of the body wall. An inspection of Fig. 22 will show you how much you can expect to find.

THE SIPHON

In the male, the removal of the skin in the ventral pelvic region of fresh specimens reveals the presence of a large flat sac-like structure lying immediately beneath the

skin. (See Fig. 19.) This sac will be partly destroyed in preserved specimens which have had the posterior ventral body wall removed, but by dissecting away the skin of what remains of the abdominal wall, it will be discovered with the anterior part cut off, revealing the hollow interior. This sac has been called the **siphon.** Posteriorly, it leads by two tapering prolongations resembling wide ducts to the claspers, and each prolongation communicates with the groove of a clasper. (See Fig. 23.) The function of this peculiar sac is not clear, but its connection with the claspers suggests a sexual function. It may be that it takes in water and functions as a squirting or flushing apparatus. Examine it carefully and see if you can suggest a function.

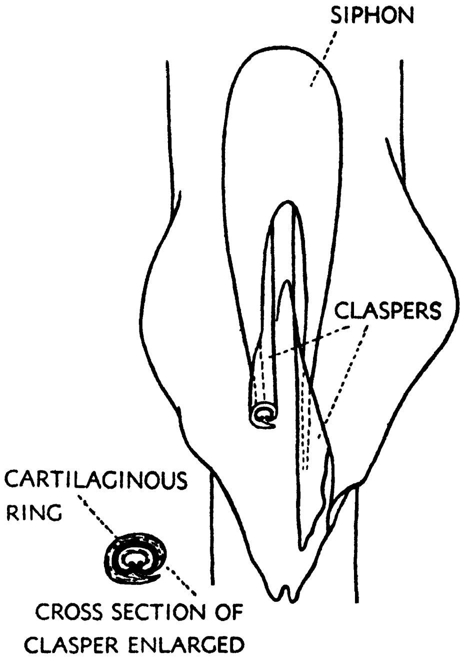


Fig. 23.—Relation of the siphon to the claspers.

Drawing.—Draw a diagram of the pelvic region of a male specimen to show the position and extent of the siphon.

Laboratory Note.—Write a short note on the relation of the siphon to the claspers and on its possible function.

OPENING THE BODY CAVITY OF A FRESH SPECIMEN

With the fish lying on its back and fixed to the dissecting board, insert a blade of the large scissors into the body wall about half-way along the abdomen and in the middle line. Having entered the body cavity, keep the inserted blade of the scissors well up so as not to cut any internal organs, and cut through the body wall in the middle line forward to the pectoral girdle. Turn the fish round and continue the cut to the pelvic girdle, but in the male first free the siphon and turn it back so as to preserve it from damage.

OPENING THE PERICARDIAL CAVITY AND THE BRAIN CASE

Before the specimen is placed in preservative both the pericardial cavity and the brain case must be opened in order to admit preserving liquid (70 per cent. industrial methylated spirit or 10 per cent. formalin) to the heart and brain respectively. The ventral wall of the pericardium is protected by the pectoral girdle, which is conveniently rather domed in shape at the centre. Remove any skin overlying the centre of the girdle and, having exposed the cartilage by scraping, hold the laıge scalpel with the flat of the blade horizontal and take off a few very thin slices from the girdle until a hole appears. Then with great care to avoid damage to the heart, make the aperture sufficiently large ($\frac{3}{8}$ inch or 1 cm. across) to admit preservative readily.

To open the brain case, remove the skin from the top of the head between the eyes as directed previously (page 60), and bare the top of the chondrocranium. Then by horizontal thin slices, cut away a middle portion of the cartilage until an aperture $\frac{3}{8}$ inch (1 cm.) across has been made, exposing the cerebellum of the brain. (See Fig. 24.) You should be particularly careful not to injure the brain in any way during the operation, and to confine the cutting to the area mentioned.

Before proceeding further, look on the inside of the body wall a short distance (about $\frac{1}{2}$ inch or $1\frac{1}{2}$ cm.) from the

median incision, and see the lateral abdominal vein, the superficial anterior end of which has already been recognised near the pectoral girdle (page 69).

THE ABDOMINAL VISCERA

On opening the body cavity of a fresh specimen, you will observe that the various organs constituting the viscera[1] slide over one another readily, so that they become

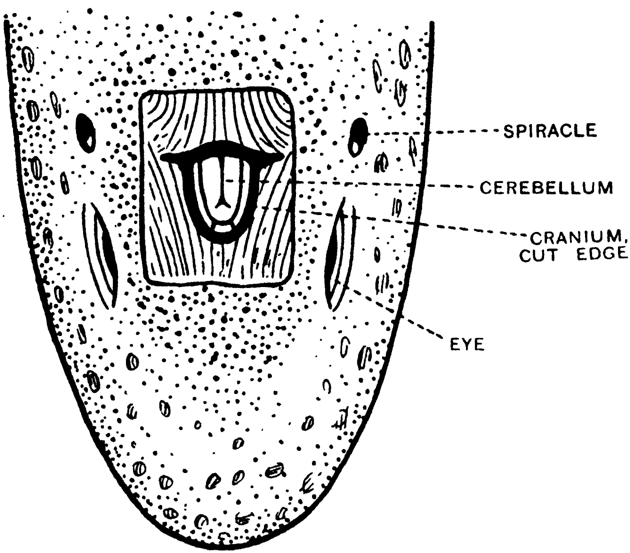


Fig. 24.—To illustrate opening of the chondrocranium to admit preservative to the brain.

displaced. In preserved specimens this will not occur, and the organs will remain more or less in their natural compact position. In life, the surfaces of the viscera are slippery

[1] "Viscera" is a collective term used for the internal organs, and is most generally used in the plural, the singular "viscus" being rarely used.

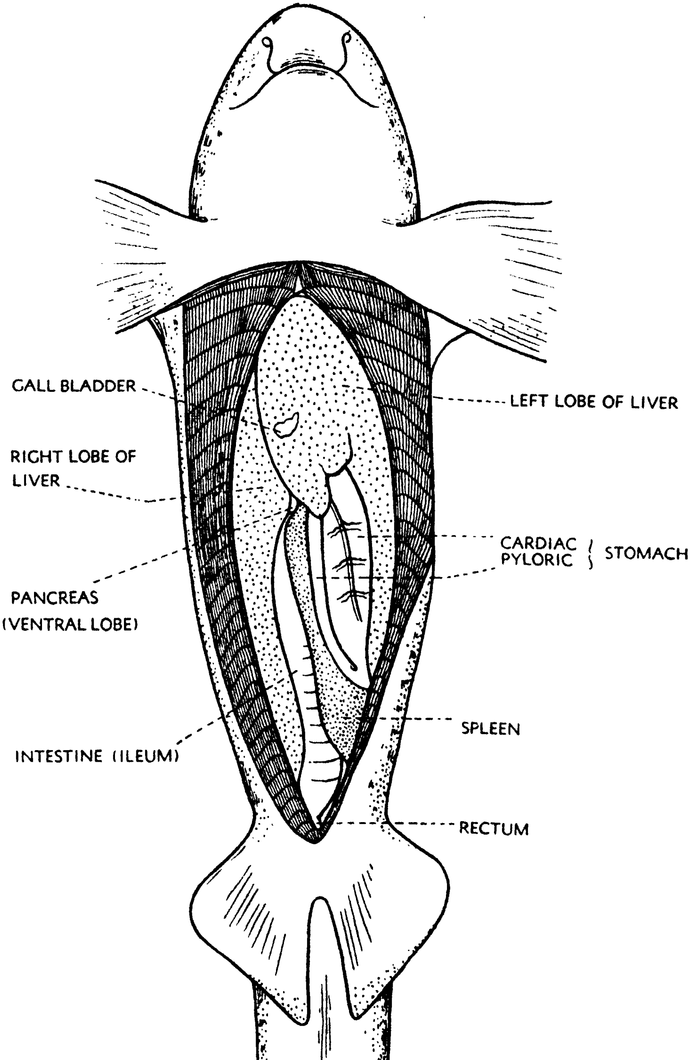


Fig. 25.—Undisturbed abdominal viscera of a young female dogfish.

because they are covered with a sheet of moist tissue which is continuous with the lining of the body cavity. This tissue is the coelomic epithelium called **peritoneum**, and it secretes a fluid—the **peritoneal fluid**—which keeps its surface moist. It is obviously an advantage that the various organs should be able to move without friction in the living animal, and organs are continually moving, especially the gut with its wave-like expansions and constrictions, or peristaltic movements, which cause the contained food to pass on. In the preserved animal the peritoneal fluid is changed by the action of the preserving liquid, and the organs will not slide over one another so readily.

As is usual among the vertebrates, the largest organ in the body is the **liver**, which you will find on each side of the body cavity. Its two huge lobes extend nearly the whole length of the abdominal cavity. It is of a pale brownish-yellow colour when fresh, but somewhat darker after preservation. Quite frequently the left lobe is shorter than the right. Indication of sub-division into smaller lobes is but slight.

The parts of the alimentary canal immediately visible will be the stomach and intestine. The **stomach** is U-shaped, and occupies a large part of the body cavity, extending well back towards the pelvic region. The left limb of the U—*i.e.* the right side as you see it—is wide, and is called the **cardiac portion** because it immediately follows the **cardia** or place where the gullet is continuous with the stomach. Over its surface you will see the ramifications of an artery and a vein, side by side. The second part of the stomach—the right limb of the U—is the **pyloric portion**, so called because it leads to the intestine by a constrictable passage called the **pylorus**. It is much narrower than the cardiac part along which it doubles forward and to which it is closely applied and attached by a sheet of peritoneum called **mesentery**. At its anterior end (the pylorus) it leads to the short, somewhat swollen part called the **duodenum**, or first part of the intestine, which in turn is followed by the **ileum** or second part of

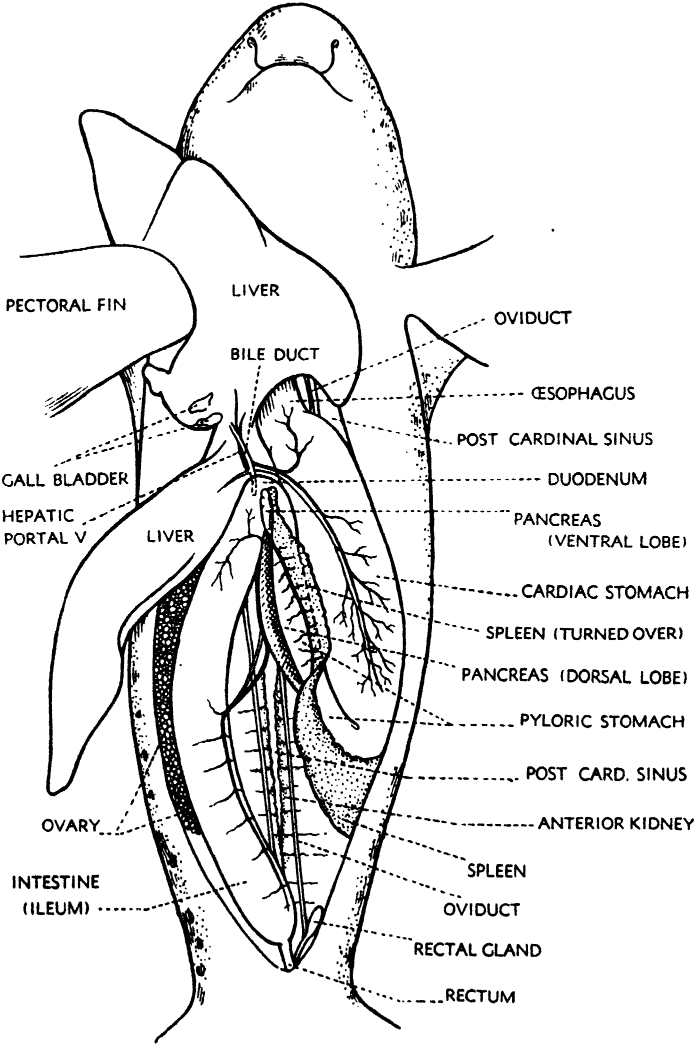


Fig. 26.—Abdominal viscera of a young female dogfish.

the intestine. Narrow at first, the ileum soon enlarges to a wide tube closely invested by the right lobe of the liver. At its posterior end it narrows down to pass into the short, narrow **rectum,** which leads to the cloaca.

Between the intestine and the pyloric portion of the stomach you will see a dark red, narrow body closely attached to the stomach and ending posteriorly in a large triangular lobe which fits round the bend of the stomach. This is the **spleen.** At the anterior end of the spleen, close to the duodenum, is a small whitish body, which is the ventral lobe of the **pancreas,** the greater part of which gland lies dorsally between the stomach and the intestine.

Generally, in preserved specimens, before the viscera are disturbed, other abdominal organs will not be immediately visible. But in mature female specimens a part of the **ovary** may be seen protruding between the other organs; in which cases it is easily recognised by the rather large eggs.

The condition of the reproductive organs will depend upon the maturity of the fish. In the female, as just mentioned, if the ovary is mature, the eggs will be large. You will observe that we do not speak of the "ovaries," since in the female dogfish there is but one ovary, the right one, the left not having developed. When such large eggs are produced, there is insufficient room for two ovaries; the same condition is seen in birds where the eggs are very large also. The ovary is suspended from the mid-dorsal line of the body cavity by a sheet of peritoneum called the **mesovarium.** If the ovary is moved across to the animal's left, a blood vessel will be seen to be spreading over the mesovarium. This is the genital or **ovarian vein,** leading to the posterior cardinal sinus. At the anterior end of the mesovarium are the **ovarian arteries** which are branches of the coeliac artery. If the ovary is to be retained, it must be handled with care, because the mesovarium is very delicate and easily torn. The ripe ovary is a soft mass rather difficult to handle, because the eggs are easily burst. Note how the large size of the eggs is due to food material or yolk so that the young fish, on hatching,

is large enough to look after itself at once. In immature female specimens the disposition of the ovary is easily made out and its suspension can be observed readily.

On each side, close to the dorsal body wall, is an **oviduct** or Müllerian duct, held in place by a suspensory sheet of peritoneum. Here again the appearance varies with the sexual maturity of the fish. In the immature condition it is seen as a whitish straight tube. Towards its anterior end it has a prominent swelling called the **oviducal gland** or **shell gland**, for it is here that the horny egg cases are secreted. In the mature female the oviducts are large and each is likely to contain an egg in its case on its way down to the exterior. In such instances the wall of the duct is highly vascular, and the colour a bright red in fresh specimens, owing to the large amount of blood in the very numerous blood vessels; in fact it gives the appearance of being bathed in blood. The arteries supplying the oviducts arise from the dorsal aorta.

In the male there is a pair of sex glands called **testes,** one testis on each side. In preserved specimens they resemble the liver in texture and often in colour, but in fresh specimens they are often quite red, due to the abundance of blood vessels. They are large organs and reach well back in the body cavity, and in mature specimens the two are united at their posterior ends. You will find that, in fresh specimens even more so than in preserved, the testes need to be handled with care since they are easily detached from their suspensors of peritoneum called **mesorchia.** The suspensors are very delicate and easily damaged, and when they have been torn, the testes appear to be loose in the body cavity. Special care is necessary not to damage the anterior part of the attachment. The **spermatic arteries,** corresponding to the ovarian arteries in the female, arise as branches of the coeliac artery.

From each testis at its anterior end, and passing along the mesorchium, are a number of fine tubules called **vasa efferentia.** These tubules lead to a duct called the **vas deferens,** which forms a compact mass of convolutions. In order to see the vasa efferentia, it is best to look on the

dorsal side of the testis by very carefully raising it from the body wall. The vas deferens overlies (*i.e.* is on the ventral side of) a lobulated reddish body, or **anterior mesonephros,** sometimes called the epididymis. You will notice that a thickish layer of peritoneum covers the vas deferens, masking it to a great extent.

The main bodies of the **kidneys** are situated well back in the posterior part of the body cavity and close against the dorsal body wall. They are covered with a heavy sheet of peritoneum, and will not be visible except in fresh specimens where their dark red colour may be recognised through the peritoneum.

Drawing.—In an outline of the fish, make a drawing to show as much of the viscera as possible, labelling each organ.

Laboratory Notes.—Write notes in your laboratory book on the positions of such organs as cannot be shown in your drawing.

The Alimentary Canal

The alimentary canal or food channel begins at the mouth and ends at the cloaca. You have already noted the position of the mouth and have examined the teeth *in situ* and microscopically, and you have also seen that an oronasal groove connects the mouth with the nostril on each side.

The mouth leads to the **buccal cavity,** which in turn passes, without interruption, to the **pharynx.** With fresh specimens it is easy enough to open the mouth to examine the buccal cavity and pharynx; but with preserved specimens this may be impossible, the muscles of the jaws having " set " in a contracted condition. In such cases, the demonstrator may prepare for you a demonstration specimen. You will do the same dissection yourself later on, in connection with the circulatory system, and, should the preparation of a demonstration specimen be impossible, you can delay the examination of this part of the alimentary canal till then.

The specimen is cut longitudinally from the angle of the mouth along the ventro-lateral side of the head to a place

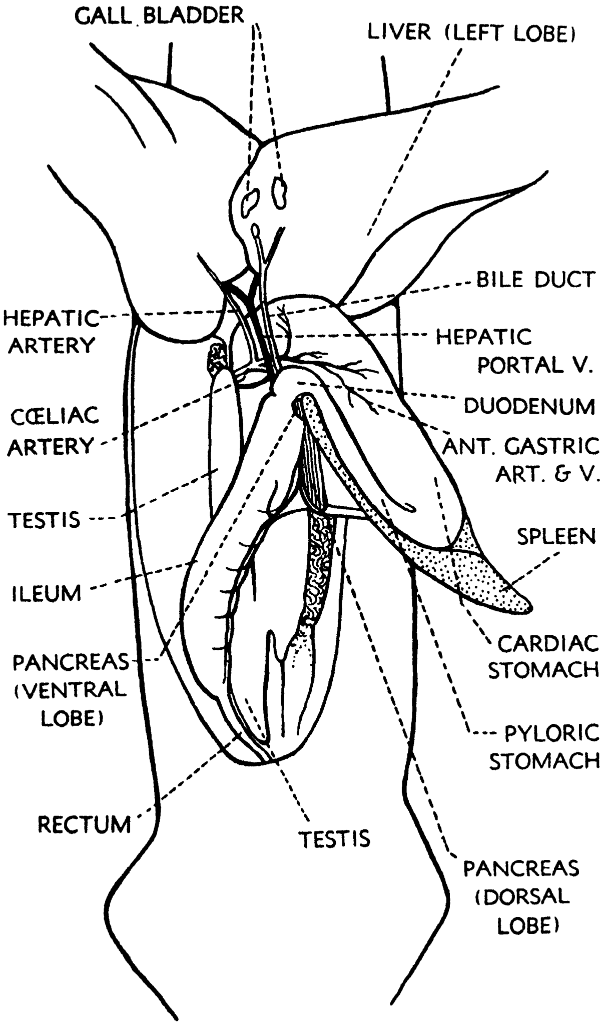


Fig. 27.—The alimentary canal.

just beyond the level of the posterior end of the pericardium. From this point a transverse cut is made behind the pericardium, and the floor of the pharynx can then be turned over to one side, exposing the whole of the interior.

From the outside insert a seeker into the spiracle, and note where it appears on the inside. This internal opening of the spiracle marks the posterior limit of the **buccal cavity** which thus extends from the mouth to the spiracle. Note particularly the distance between the internal openings of the spiracle and the first gill cleft, and compare this with the distance externally. On the floor of the buccal cavity you will see the so-called **tongue.** Note that it is firm and rigid, and is not protrusible; it is supported by the basihyal cartilage. Look at a prepared skeleton of the visceral arches and note the position and shape of the basihyal cartilage. (See Fig. 4.)

The **pharynx** is a part of the alimentary tract, but is also respiratory in function. At its sides are the openings of the spiracles and gill pouches which place it in communication with the exterior. Here, then, the body wall and the gut wall are fused together and pierced by apertures, a condition quite unlike the relationship in the trunk, where a coelom or body cavity intervenes between the gut and the body wall. At intervals along the arch you will see small nodular projections; these are called **gill rakers.** They are poorly developed as compared with the gill rakers of bony fishes, where they play the part of a sieve. The food of bony fishes most commonly consists of small creatures which might easily be carried back to the surrounding water by the respiratory current, but the dogfish feeds mostly on larger prey which could not escape from the pharynx through the internal gill slits to the water outside. Once again note the relative positions of the spiracle and the first gill cleft internally and externally. Posteriorly the pharynx narrows to the gullet or oesophagus.

Drawing.—Make a drawing to illustrate a side view of the interior of the buccal cavity and pharynx, indicating the gill clefts, spiracle, angle of the mouth, and the tongue.

The **oesophagus** or gullet is a short, flattened tube leading from the pharynx to the stomach. To expose it, turn the left lobe of the liver forwards as shown in Fig. 27. It is a tube capable of considerable expansion and very muscular, since its function is to swallow food, which is taken whole. It is the first part of the alimentary canal to enter the perivisceral cavity.

The U-shaped **stomach** follows the oesophagus. Note the size of it and the extent of abdominal space it occupies. Lift it and note that it is attached to the mid-dorsal body wall by a sheet of peritoneum called **mesentery.** In reality this mesentery is double, since it is merely the continuation of the peritoneal covering of the gut and internal body wall already referred to as providing a moist surface. Thus the stomach, like the rest of the alimentary canal in the abdominal cavity is in a kind of sling. You will notice that the mesentery has another important function to perform besides supporting the gut. In it run blood vessels and nerves connected with the gut wall; it is obvious that such structures as blood vessels and nerves could not be loose in the abdominal cavity.

The cardiac portion of the stomach is wide, for the dogfish is a voracious feeder, and eats anything that comes in its way. Here, too, digestion begins, there being no digestive action in the buccal cavity, pharynx, or oesophagus. You will notice that it is well supplied with blood vessels both on its ventral and dorsal sides, and close observation will show the presence, side by side, of two vessels, one an artery and the other, the darker, a vein. The pyloric portion is a much narrower tube; great width is here unnecessary, since the food is partially digested before it enters this part of the stomach. Note that here also is a rich supply of blood vessels, best seen if the narrow part of the spleen is turned over.

At the point where the pyloric portion of the stomach is continued into the intestine, you can feel a thickened ring round the gut wall. This is the **pyloric sphincter muscle.** The name sphincter is given to a circular muscle which has the power of closing a tube or aperture. The

passage which this sphincter controls is called the **pylorus**; thus, until the food is converted into a condition suitable for its reception by the intestine, it is not allowed to pass.

The part immediately following the pyloric sphincter is the **duodenum** or first part of the intestine. It is quite short, but its limits will be better seen later on when you examine its interior. For the present it may be said that it occupies little more than the bend in this part of the alimentary canal.

Externally, the duodenum passes insensibly into the **ileum**, which gradually becomes quite a wide tube. As in the case of the stomach, observe that it is supported by mesentery. Feel the ileum and note that it is fairly firm to the touch. This is due to the presence, inside, of the **spiral valve**, the turns of which are indicated by blood vessels running transversely across the ileum. Once again you will notice that a plentiful blood supply is provided. In a mammal with a body as large as that of a dogfish, the intestine would be much longer and much coiled, but the dogfish has acquired relatively the same absorptive area as the mammal by the device of a spiral valve.

Beyond the spiral valve the intestine narrows considerably to enter the last part of the intestine, called the **rectum**. To follow the rectum, it will probably be necessary further to open up the pelvic region of the body. Cut the body wall in the middle line from the interior, upwards to the skin, so that the back of the scalpel will lie against the internal organs. The rectum ends posteriorly in the cloaca.

Glands of the Alimentary Canal

LIVER. You have already noted the two large lobes into which the liver is divided, and that the left lobe is frequently shorter than the right. The left lobe is itself subdivided to a slight extent at its anterior end so as to form what is sometimes spoken of as the median lobe. The right and left lobes are attached to one another anteriorly and to the anterior wall of the body cavity—the pericardio-peritoneal septum—by a strong sheet of peritoneum called the **falciform ligament**.

The **gall bladder** is embedded in the median lobe. Separate the anterior portions of the lobes and you will see it on the inner surface, as an irregular dark area with a membranous appearance. It frequently appears also on the ventral side of the lobe (see Figs. 25 and 27). From the gall bladder trace its duct, the **bile duct.** It is whitish in colour and lies along the edge of the mesentery between the liver and the stomach and intestine and alongside a large blood vessel. It enters the intestine at the beginning of the ileum. A tributary duct from each lobe of the liver joins the bile duct.

PANCREAS. The ventral lobe of the pancreas has already been noticed as a whitish body in the pyloric bend of the gut. The dorsal lobe, which is continuous with the ventral lobe is elongated and lies between the pyloric stomach and the intestine. Separate the pyloric limb of the stomach and the ileum and find the dorsal lobe. The **pancreatic duct** leaves the ventral lobe and runs along the wall of the intestine before entering at the beginning of the ileum.

THE SPLEEN. Owing to its close proximity to the stomach, the spleen is again referred to here. It is a gland with no duct, and it therefore has no direct connection with the alimentary canal. This ductless gland produces red blood cells, and also destroys such as have for any reason become inefficient or worn out. Though a ductless gland, it is not an endocrine organ.

THE RECTAL GLAND. This gland lies at the junction of the ileum and rectum. It is a small, rather hard cylindrical structure at the edge of the mesentery. Textbooks seldom refer to the function of the rectal gland, and it may be assumed that little conclusive knowledge is available concerning it.

Drawing.—Make a drawing, inside an outline of the fish, of the alimentary canal, the liver with gall bladder and bile duct, the pancreas and its duct, the spleen and the rectal gland.

The Vascular Supply of the Alimentary Canal

You will have learned from your textbook that the alimentary canal and the glands associated with it are supplied with oxygenated blood by the coeliac artery, anterior mesenteric artery, lienogastric artery, and the posterior mesenteric artery. The blood thus arriving at the gut is returned as deoxygenated and food-laden blood to the liver by means of the hepatic portal vein. It is most important to remember that all the blood from the alimentary tract, as a result of the digestive processes, contains food material and other substances which must be "censored" before they are allowed to enter the general circulation. Dangerous substances must be rendered innocuous, and the various food constituents must pass on only in the correct proportions. This, together with the production of bile, is the important work of the liver, which you have noticed is the largest organ in the body, as it well needs to be.

Examine first the intestine. Along the posterior half and on its dorsal side you will find two blood vessels running side by side. One is an artery and the other is a vein, the vein being the more prominent. The artery is the **anterior mesenteric artery** which brings oxygenated blood to the posterior half of the intestine. It sends branches along the attachment of the spiral valve. Tracing it forwards, you will find that before reaching the intestine it has crossed the body cavity in the mesentery, having made its appearance in the middle line between the viscera, where it arises from the dorsal aorta. The vein is the **posterior intestinal vein** which removes the blood from this part of the intestine. Follow the vein back to its origin in the rectal gland. Tributaries to the vein are to be seen along the line of attachment of the valve accompanying the branches of the artery. The vein also leaves the intestine alongside the anterior mesenteric artery, but on reaching the posterior (caudal) end of the pancreas it is joined by another vein, the **posterior lienogastric vein.**

Follow the posterior lienogastric vein back and you will find that it is formed by the union of two veins, one from

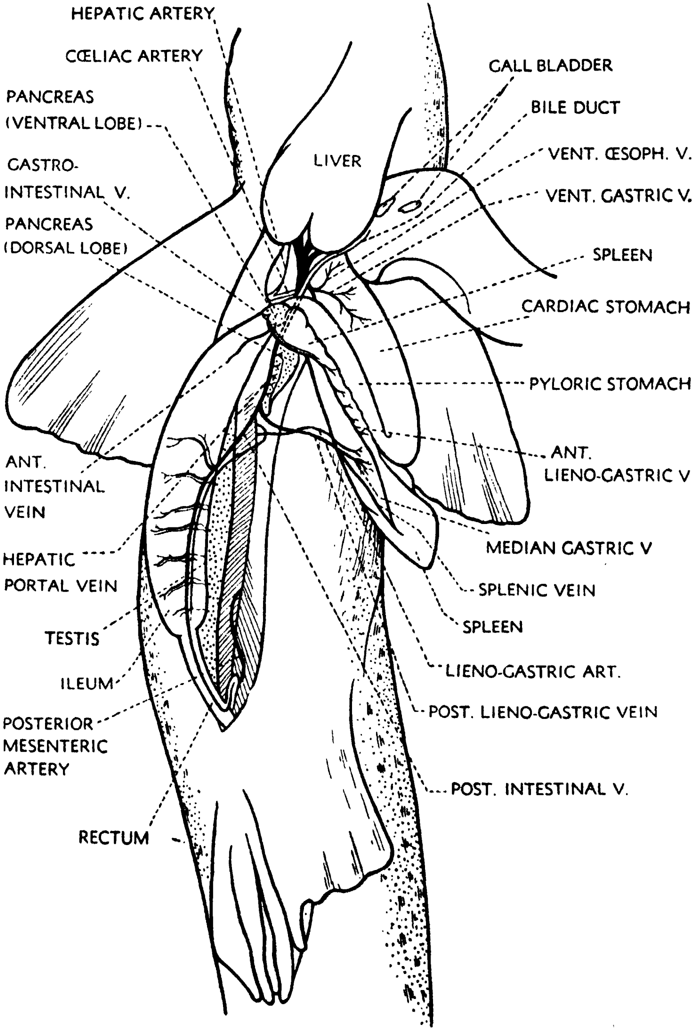


Fig. 28.—Alimentary canal, its glands and vascular supply. The spleen is turned over.

the dorsal side of the posterior cardiac portion of the stomach and the other from the triangular lobe of the spleen. That from the stomach is the **median gastric vein,** which is only about a quarter of an inch or six millimetres long after leaving the stomach wall where it originates in

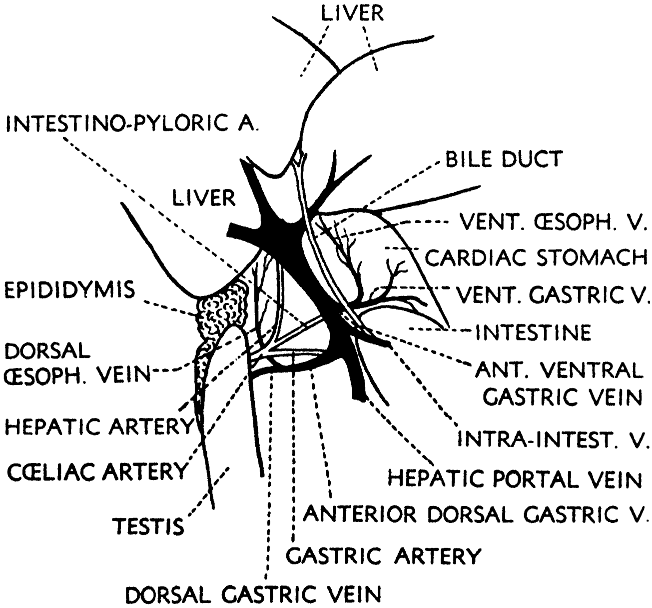


Fig. 29.—Detail of vessels seen on the right anterior side of the stomach.

small tributaries spread in all directions; the other, much longer, from the spleen, is the **posterior splenic vein.**

The **lienogastric artery** runs parallel with the posterior lienogastric vein. It appears in the body cavity from between the viscera in the middle line close to the anterior mesenteric artery, and passes to the spleen and bend of the stomach. The gastric branch is closely associated with the median gastric vein.

The origins of the anterior mesenteric artery and the lienogastric artery from the dorsal aorta can best be seen by pushing the viscera over to the animal's left side, when it will be found that, near their origins, the anterior mesenteric artery is the more anterior of the two, and that the two vessels cross soon after leaving the aorta.

The posterior intestinal and posterior lienogastric veins unite at the pancreas to form the **hepatic portal vein,** which runs forward closely attached to the pancreas and thence parallel with the bile duct to the liver in the mesentery which joins the pyloric end of the stomach to the liver. A series of veins leave the pancreas throughout its length to enter the hepatic portal vein.

The blood vessels of the anterior parts of the gut are named from the areas they serve. Between the elongated part of the spleen and the pyloric part of the stomach you will see a vein receiving numerous tributaries from both these organs; this is the **anterior lienogastric vein.** It runs forward ventral to the hepatic portal vein and curves round the pancreas between it and the duodenum, at which point it is joined by the **anterior intestinal vein** from the ventral side of the anterior intestine. The two veins thus form a short common vessel called the **gastro-intestinal vein** which enters the hepatic portal vein. The anterior intestinal vein actually arises inside the intestine on the first fold of the spiral valve and eventually pierces the wall of the intestine to appear on the surface; it receives a tributary from the ventral lobe of the pancreas and from the pylorus.

Turn the intestine over and across to the animal's left side, and the liver forwards, so as to expose the anterior part of the cardiac portion of the stomach and part of the oesophagus. (See Fig. 29.) Here you will see the remaining veins leading to the hepatic portal vein. From the dorsal wall of the stomach comes the **anterior dorsal gastric vein** formed by two tributaries, the **dorsal oesophageal vein** and the **dorsal gastric vein**; from the ventral side of the stomach comes the **anterior ventral gastric vein,** likewise formed by two tributaries, the **ventral**

oesophageal vein and the **ventral gastric vein.** A vein which makes its appearance for only a short distance along the duodenum, having come from the folds of the spiral valve internally, will also be seen to enter the hepatic portal vein, usually between the junctions of the anterior dorsal and anterior ventral gastric veins with the hepatic portal vein. It is called the **intra-intestinal vein.**

It is little wonder that with so many tributaries the hepatic portal vein should be so large shortly before it enters the liver; its huge size should be noted and its branching as it enters the liver.

The arteries of these areas show considerable variation in detail, but in any case the **coeliac artery** is responsible for the distribution of oxygenated blood to the more anterior parts of the alimentary canal.

With the viscera still in the same position, look for the coeliac artery. It will appear as a short trunk close to the wall of the anterior end of the stomach, and it very soon divides into three main branches: (1) the **hepatic artery** which is a rather small vessel since it has to bring only oxygen to the liver tissue, food arriving in plenty by the portal vein; it runs straight forward to the lobes of the liver. (2) The **intestino-pyloric artery** which supplies the region of the pylorus, the pancreas, the anterior lobe of the spleen and the neighbouring stomach and intestine, both on the walls and the spiral valve. There are the **pyloric artery** which gives off an **anterior lienogastric artery,** the **intra-intestinal artery** for the spiral valve, and the **anterior intestinal artery** all along the intestine. (3) The **gastric artery** which almost immediately branches over the stomach and oesophagus accompanying the corresponding veins.

The **posterior mesenteric artery** can be seen ending at the rectal gland. Follow it from the gland when it will be seen to disappear in the middle line at about the level of the posterior end of the ovary or testes, where it originates from the dorsal aorta.

Drawings.—Several drawings are necessary for a record of the distribution of the blood vessels to the alimentary canal and its

glands, but the most comprehensive may be made from a left ventro-lateral view of the animal with the liver placed forwards and the intestine held up.

ALIMENTARY CANAL—CONTENTS AND INTERNAL STRUCTURE

Having now examined the exterior of the alimentary canal, the glands associated with it and its vascular system, we may now consider the interior and dissect the various parts irrespective of damage to the blood vessels of the gut.

With scissors, open the cardiac portion of the stomach throughout its length on the ventral side. In the male, the incision may be continued into the oesophagus, but in the female the oesophagus must, for the present, remain intact.

It will be necessary first to deal with the contents of the cardiac portion of the stomach, because you will be anxious to be rid of them as soon as possible. You will probably be struck by the large number of small, thread-like round-worms which are invariably present in the alimentary canal of the dogfish. These are nematode worms whose presence does not seem to discommode the dogfish in any way, and they are probably commensal rather than parasitic; but whether parasitic or commensal, the voracity of the dogfish provides amply for both host and guests—or is the presence of so many parasites the urge for the fish's voracity? It is clear that these nematode worms are able to resist the action of the digestive fluids, and carry on respiration under restricted conditions—features characteristic of internal parasites.

It is interesting to try to identify some of the animals or parts of animals which have been swallowed. It will be evident from the size of some of them that the oesophagus is dilatable. Fishes, crabs, shellfish, and squids are all likely to be met with. However, the important thing to note is that the contents, many of which are identifiable, are only partially digested.

Before removing the contents of the cardiac portion, continue to cut along the pyloric part, in order to have the

contrast in contents before you. Here you will notice that the food has undergone a change, and it now resembles a mush, so that identification of creatures constituting the food is no longer possible. There is, therefore, no need for bulkiness as in the cardiac portion.

Wash out the contents of the stomach under a tap, in order to be able to examine the nature of the interior of the stomach wall. The wall will be seen to be thrown into a series of longitudinal folds to allow for dilatation and by which the glandular surface is increased. The folds are very prominent in the cardiac and continue for some distance into the pyloric part; but the greater part of the latter has smooth walls.

The interior of the oesophagus shows longitudinal muscular ridges as a prominent feature, for the walls are dilatable and adapted for swallowing.

Continue the cut through the pylorus, and after washing note the thickness of the sphincter muscle and the size of the aperture. Then cut a little farther into the intestine past the duodenum and about one and a half inches, or three and a half centimetres, along the ileum. When cleaned thoroughly, examine the inside wall of the duodenum and notice how it differs from that of the stomach. The wall is thrown into thick longitudinal folds ending abruptly in a ridge.

Having cut for a short distance along the wall of the ileum, you will be able to see the beginning of the spiral valve, and look for the internal openings of the bile duct and pancreatic duct.

The **bile duct** opens on a small papilla behind (dorsal to) the beginning of the spiral valve; if the valve at this point be moved over to the animal's left, the papilla may be seen at about an inch or less (2½ cm.) from the duodenum. It may be difficult to find in preserved specimens owing to the strong wrinkling of the ileum wall. The **pancreatic duct** is short, and leaves the posterior end of the ventral lobe of the pancreas to run a short distance in the wall of the duodenum. Its internal opening is immediately at the beginning of the ileum.

An examination of the anterior end of the **spiral valve** will show that it resembles a spirally wound strap, the outermost turn giving the appearance of a long cone. By attempting to unwind it, you will realise that there are several turns tightly wound upon one another. The simplest way to demonstrate the spiral attachment to the ileum wall, which begins at between one-third and one-half the length of the ileum, is to make a clean cut with the scissors, a sharp scalpel, or a razor, completely across the ileum a little beyond half-way along it. In the section thus obtained, after thoroughly cleaning, the spiral arrangement is obvious. A seeker can be started at the outside of the cavity next the wall, and by following the valve it will arrive at the centre, having completed the spiral. By feeling with a seeker in the severed posterior portion of the ileum, the spiral attachment to the wall can also be determined.

Another method, which takes more time, is to cut a series of rectangular " windows " between the lines of blood vessels showing externally, and afterwards trimming the edges up to the actual attachment of the valve. By directing a seeker through one of the openings in a forward direction, there will be no obstruction, but in the reverse direction the attachment of the valve will be felt.

The course of the food down the ileum should now be clear, for you will realise that on entering the ileum from the duodenum, the food will be passed on along a descending spiral plane. Thus a very large surface is available both for digestive action and for absorption of digested food by the venous capillaries of the wall of the ileum and the spiral valve.

Finally comes the rectum, which receives the duct of the rectal gland already referred to. If the rectum is opened and its contents washed out, the entrance of the duct can be determined by making an opening in the duct and passing a bristle down it. The rectum is not important from a digestive or absorptive point of view, and its vascular supply is quite meagre. It is chiefly concerned with the ejection of faeces. The actual opening of the

rectum into the cloaca will be seen in a later dissection, but a seeker passed down from inside makes it quite clear that it leads to the cloaca and thence to the exterior.

If you have not already done so, it will now be convenient to pass a seeker from the posterior end of the body cavity to the abdominal pore on either side, from which aperture it will appear.

Drawing.—Make a drawing to illustrate the spiral valve.

Laboratory Note.—Make a note, in your laboratory note-book, of the nature of the contents of the stomach, including a reference to the nematode worms.

THE VASCULAR SYSTEM

This system includes the pericardium, the heart, the blood sinuses, veins, arteries, and capillaries; the last, being microscopic, do not concern us here. You have already become acquainted with that important part of the vascular system called the hepatic portal system, with the arteries supplying the alimentary canal and its glands, and with the anterior ventral cutaneous vein and its tributaries.

The position of the **pericardial cavity** lined by the pericardium and containing the heart has been noticed in a general way, but it is important to know that the anterior end of it reaches as far forward as the second gill cleft, and that there are two gill clefts posterior to the pericardium. Separating the pericardial from the peritoneal or general body cavity is a transverse partition called the **pericardio-peritoneal septum.** Later, you will find that this septum is pierced by a canal, the **pericardio-peritoneal canal,** which places the two coelomic cavities in communication with each other.

Examine carefully the museum preparation of the pectoral girdle, and note the concavity in the middle of the coracoid portion. (See Fig. 9.) This supports the ventral wall of the pericardial cavity. Above and at the sides, the pericardium is protected by the basibranchial

cartilage in the middle and the curved fifth ceratobranchial cartilage at each side.

It is usual to begin the study of the vascular system by examining the heart. In order to do this, the pericardial chamber must be completely exposed, an operation which involves slicing away the ventral portion of the pectoral girdle and during which certain vessels will be cut across. With the large scalpel held horizontally, cut away the cartilage from the sides of the aperture, already made

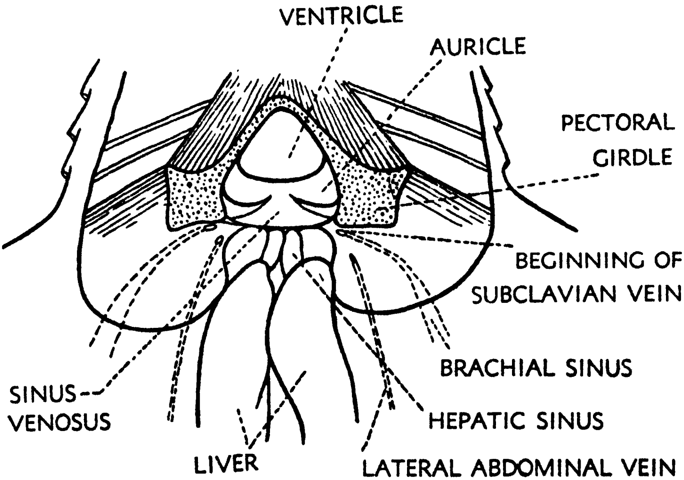


Fig. 30.—Pericardial cavity partly exposed. Note the position of the subclavian vein.

for admitting the preservative, to the extent shown in Fig. 30. You will then see, close to the posterior edge of the sectioned girdle, the cut end of a blood vessel. Carefully insert a seeker into this and, without forcing, you should be able to pass the seeker in either of two directions: (1) backwards towards the inner and dorsal edge of the pectoral fin, or (2) downwards (dorsalwards) in the direction of the posterior corner of the pericardial cavity. In the first case you pass the seeker into the brachial sinus and

can feel it near the surface of the fin. If the skin has been removed from the base of the fin, with the back of a scalpel clear away the connective tissue between the fin muscles and the body wall muscle; look on the inner side (dorsal aspect) of the fin muscles, and you will see the inserted seeker in the sinus. In the second case the seeker enters the subclavian vein.

Near the cut end of the vessel referred to above, but posterior to it and nearer the middle line, you will see another vessel cut across. This is the lateral abdominal vein. Insert a seeker into it and notice that it passes into this vessel.

You should now try to reconstruct the courses of these vessels. **The lateral abdominal vein** traverses the body wall on its inner side near the middle line. On reaching the pericardio-peritoneal septum—only about $\frac{1}{4}$ inch or $\frac{1}{2}$ cm. from the middle line—it joins the pectoral anastomosis which passes along the posterior edge of the pectoral girdle. Very soon the anastomosis is joined by the brachial sinus. These two vessels then form the subclavian vein.

The lateral abdominal vein originates posteriorly, in the pelvic region, from two veins, one from the cloaca (**cloacal vein**) and one from the pelvic fin (**femoral vein**); these two unite to form the **iliac vein**, which joins a transverse **pelvic anastomosis** between the two lateral abdominal veins. This anastomosis passes transversely along the dorsal side of the pelvic girdle. Cut cleanly through the pelvic girdle, but not deeper, and you will see the anastomosing vessel cut across. In the middle line you may see another small vessel joining the anastomosis; it is the **rectal vein** coming from the wall of the rectum and neighbouring body wall. The fact that the rectal vein enters the pelvic anastomosis is sufficient to show that no absorption of food material occurs in the rectum, otherwise the vein would join the hepatic portal system.

Slit open the pelvic anastomosing vessel from its cut end on one side, and a short distance along it you will see the iliac vein entering it. Do not track the iliac vein to find the femoral and cloacal veins, as time will not permit.

The Heart

Having fully exposed the pericardial cavity by removing still more of the pectoral girdle, the heart may now be examined. The large conical **ventricle** with its apex forwards is the most prominent of the chambers; it is ventral in position and has only a single cavity. It is pale in colour owing to its thick muscular wall through which the colour of the contained blood cannot be seen; it is thus eminently suited to function as a pump. Though the ventricle contains blood which, it must be remembered, is deoxygenated, the thickness of its walls necessitates an independent blood system for the tissues composing them, and, particularly in a fresh specimen, you can readily trace blood vessels covering its ventral surface. Over the anterior surface is one network comprising the **anterior coronary vein** which runs backward at the side of the ventricle and is joined by the **posterior coronary vein** made up of tributaries spreading over the posterior part of the ventricle. A pair of **coronary arteries** also may be seen branching over the ventricle after reaching it from its apex.

Jutting out at each side of the ventricle you will see the dark-coloured **auricle**, or **atrium** as it is sometimes called. Press the ventricle very gently first to one side and then the other, and determine that the auricle is a single chamber which spreads out on the dorsal side of the ventricle. When the ventricle is moved to one side you will see clearly the position of the single connection between it and the auricle. Notice the very thin walls compared with those of the ventricle, and that they are soft and usually collapsed. Its function is to *receive* blood, and it is not directly concerned with the pumping action; hence its comparatively delicate structure.

Next, gently press the ventricle forwards, and in the posterior region of the pericardial cavity the **sinus venosus** will be seen. This part of the heart is a thin-walled triangular chamber, the broad base of the triangle lying close against the tough membranous pericardio-peritoneal septum. The apex of the sinus venosus leads to the auricle.

Now gently press the ventricle backwards, and note the narrow, tubular and thick-walled **conus arteriosus** passing from the apex of the ventricle and penetrating the anterior wall of the pericardial cavity. The coronary arteries will be seen along the conus on their way to the ventricle.

You will realise that, since the chambers of the heart are all single, the blood contained must be of one kind only; it is all deoxygenated blood brought from all parts of the body to the heart to be pumped to the gills for aeration. It is important to remember this feature of the dogfish's heart (and the heart of practically all fishes too) compared with that of higher types like the frog and rabbit.

Drawings.—1. Within an outline of the anterior end of the body, draw a diagram of the pericardial cavity with the heart exposed within it. Indicate the positions of the pectoral fins and the gill clefts in the same figure.

2. From what you have learned from your dissection, draw a figure, showing in side view the relations of the three chambers of the heart to one another.

Laboratory Note.—Write a note describing the method you adopted to open the pericardium, and name the cartilages which support the pericardium.

The Sinus Venosus and Associated Vessels

With forceps, raise the ventral wall only of the sinus venosus and make a snick in it with fine scissors. Pass in a seeker to make sure that you have cut only the ventral wall; if the seeker appears in the pericardial cavity, it should be withdrawn, for it will show that both walls have been cut. With the seeker in position, make a transverse incision right across the sinus venosus. Press the immediate surroundings so as to force out any blood in the neighbourhood, and then thoroughly wash out the contents under a running tap; if any blood or clots remain, it will be more difficult to follow details.

Take the anterior cut edge in the forceps and lift the ventral wall of the sinus forwards so as to expose the rather large **sinu-auricular aperture** which forms the communication between the sinus venosus and the auricle

or atrium. Just inside the aperture, which should be thoroughly washed, you will see the semicircular lip of the **sinu-auricular valve** which allows the blood to pass from the sinus venosus to the auricle, but not in the reverse direction. Pass a seeker into the opening and notice that it enters either side of the auricle, proving conclusively that the auricle is a single chamber.

Now seize the posterior edge of the sinus venosus and lift it back. Close to the middle line is a pair of apertures

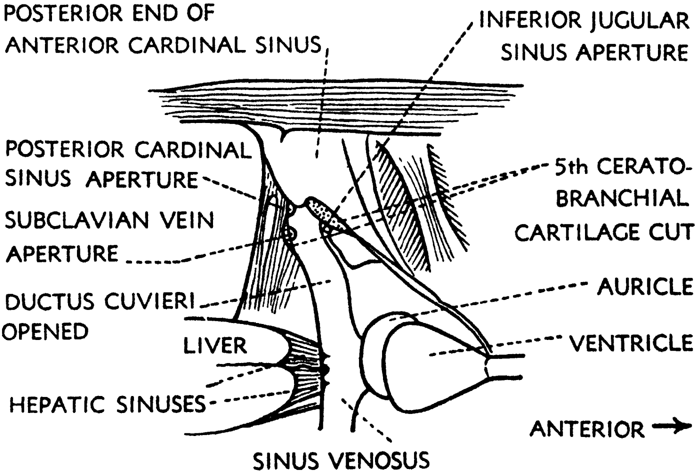


Fig. 31.—Cuvierian duct opened throughout.

with prominent lips, separated by a papilla-like protrusion. Each of these apertures leads to the **hepatic sinus** of its side. The hepatic sinuses are large, thin-walled sacs, and bring to the heart all the blood taken to the liver by the hepatic portal vein and the hepatic artery. Insert a seeker into one of the apertures and explore the extent of the sinus; you may find that the seeker passes not only to the sinus of one side but even across to the other. This is possible on account of the fact that the two sinuses are separated only by an incomplete septum.

At each of its outer extremities the sinus venosus receives a large vessel, the **ductus Cuvieri.** Continue the transverse incision of the sinus venosus and open the ductus Cuvieri. Wash out the contents thoroughly under a tap; a sable water colour brush is useful to assist in cleaning out the vessel—a camel-hair brush is rather too soft for the purpose. Note that the duct takes a course towards the dorsal side and therefore dips down in your dissection. Now once again pass a seeker into the subclavian vein and note that it appears in the ductus Cuvieri. Note the place carefully, since this vein enters the duct opposite the entrance of the inferior jugular sinus, which will be examined later.

Looking into the opened Cuvierian duct you will find at its outer end a large aperture. Directing a seeker into it in line with the duct, you will find that it can be felt at a point on the skin immediately above the fourth gill cleft. The seeker will have entered the posterior part of the **anterior cardinal sinus,** a large chamber running longitudinally above the gill pouches.

If, in the same aperture at the end of the ductus Cuvieri, you direct the seeker posteriorly, you will find that it can be seen to have entered the posterior cardinal sinus in the dorsal wall of the abdominal cavity.

The pericardium is protected dorso-laterally by the fifth ceratobranchial cartilage. In cutting open the ductus Cuvieri, you will probably have cut through this cartilage, the posterior end of which passes just ventral to the ductus. Examine the inner side of the cut end and you will find, with the air of a seeker, the opening of the **inferior jugular sinus** which enters the ductus Cuvieri opposite the entry of the subclavian vein. By inserting the seeker, you will find that the sinus takes a course close in along the lateral wall of the pericardial cavity. This completes the examination of the sinus venosus and the ductus Cuvieri, with vessels entering them.

Drawing.—Make a drawing of the opened sinus venosus and ductus Cuvieri showing the apertures of the hepatic, inferior jugular, posterior cardinal and anterior cardinal sinuses and subclavian vein.

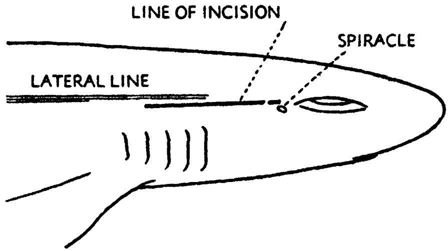


Fig. 32.—Position of the line of incision for opening the anterior cardinal sinus.

You may now proceed to examine the sinuses in more detail. We will first deal with the **anterior cardinal sinus.** As before, insert a seeker into its aperture in the ductus Cuvieri and turn the fish over, when you will be able to feel the end of the seeker on the side of the fish immediately above the fourth gill cleft. Mark the point by cutting through the skin there in a longitudinal direction. Then, withdrawing the seeker, make a bold longitudinal incision inwards and downwards from the point marked to a spot just above the spiracle (see Fig. 32). If you cut downwards only, you will find that you

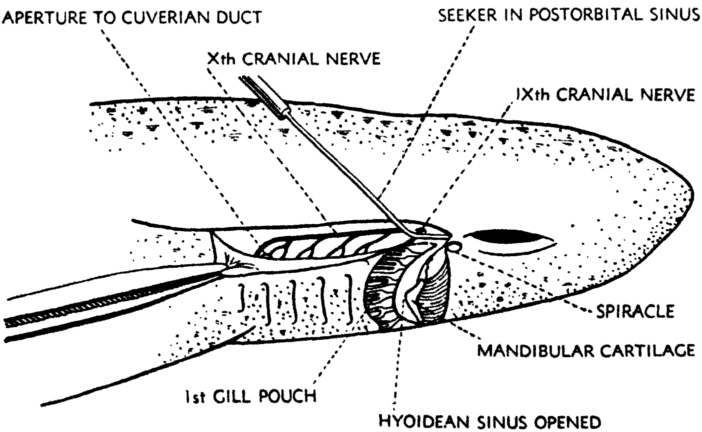


Fig. 33.—The anterior cardinal sinus opened to show its relationship to the hyoidean, postorbital, and posterior cardinal sinuses, and Cuvierian duct.

have cut into the gill pouches, and your object is to open the sinus which lies above the gill pouches. If successful, you have opened the anterior cardinal sinus almost throughout its length, and you will observe that it is a large and rather irregular space immediately above the gill pouches. It extends from the front of the first gill pouch back to a little beyond the fifth. In its floor you will see a number of nerves—the IXth and branches of the Xth cranial nerves—which will be studied later.

At the posterior end of the sinus, look for the aperture which leads to the ductus Cuvieri, about in line with the fourth gill cleft. Inserting a seeker through the aperture, cut down cleanly to the seeker so as to open the ductus throughout its length. By this means you will see the relations to the ductus Cuvieri of the anterior and posterior cardinal sinuses, the subclavian vein and the inferior jugular sinus.

Passing now to the anterior end of the anterior cardinal sinus, if the longitudinal incision extends forwards to a point above the spiracle, you will find that a seeker will pass readily from the anterior end of the sinus to the **orbital sinus,** the cavity surrounding the eyeball, where the seeker will be seen to disturb the eyeball. The actual passage is the **postorbital sinus,** which passes round the auditory capsule in the postorbital groove of the cranium.

Near to the opening of the postorbital sinus, on the latero-ventral wall of the anterior cardinal sinus, immediately behind the spiracle, is the communication with the **hyoidean sinus.** The full course of the hyoidean sinus will be followed later.

Drawing.—Make a drawing of the opened anterior cardinal sinus showing particularly the openings of the posterior cardinal sinus, Cuvierian duct, postorbital sinus, and hyoidean sinus.

Laboratory Note.—Write a note describing exactly how you proceed to expose the interior of the anterior cardinal sinus. A sketch might usefully accompany the note.

You have already located the **posterior cardinal sinus** in the dorsal wall of the peritoneal or body cavity dorsal to

the liver. In order to examine this sinus, it is better that its anterior portion, which you have seen is very wide, should have its ventral wall removed. With small scissors and forceps remove as much of the wall of one sinus as possible in the wide anterior portion. This done, you can, by a seeker, determine its form posteriorly where it narrows to a comparatively small vessel running side by side in the middle line with its fellow of the opposite side.

The anterior dilatation of the posterior cardinal sinus is not a clear space, but is traversed, especially laterally, by strands of tissue giving almost a spongy appearance. With

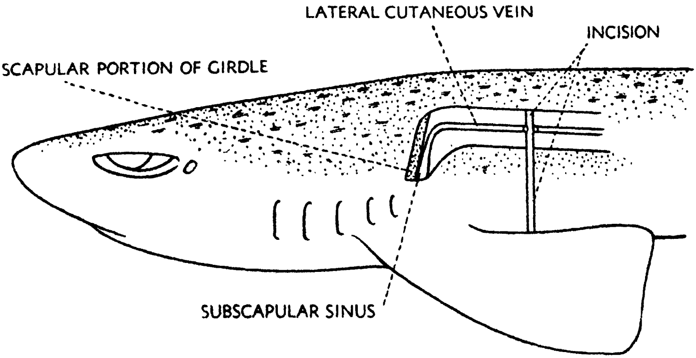


Fig. 34.—Anterior course of the lateral cutaneous vein.

a seeker, you will find that the partition between the right and left sinuses is an imperfect one. The two communicate with each other to a varying extent, and as a rule the seeker will at places readily pass from one to the other. In a later dissection you will find that between the kidneys the two sinuses unite to form a median vessel. It is here that the posterior cardinal sinuses originate by contributions from the renal veins which are invisible externally, owing to the close proximity of the sinus to the kidneys. It may be noted that the possession of posterior cardinal sinuses in the adult is a character of fishes.

Owing to the irregular nature of the interior of the posterior cardinal sinus anteriorly, it is difficult from the inside to find the place where the **lateral cutaneous vein** enters, and it is better to follow the vein itself from the lateral line, with which it is associated, to the posterior cardinal sinus.

Just behind the pectoral fin, make a transverse incision across the body wall from the mid-ventral incision to a little beyond the lateral line. Examine the anterior face of the incision at the lateral line, and you will sec the lateral cutaneous vein immediately underlying the lateral line. Insert a seeker into the vessel forwards, and with a scalpel cut down on to the seeker. On approaching the ascending scapular portion of the pectoral girdle, which encircles the body just behind the last gill slit, you will find that the vein turns sharply ventralwards alongside the girdle. Towards its end it expands slightly and the expansion is sometimes called the **subscapular sinus.** A seeker inserted here will be seen to appear in the posterior cardinal sinus.

Drawings.—1. In an outline of the body, make a drawing to show the contour of the posterior cardinal sinuses.

2. Make a drawing to illustrate the course of the lateral cutaneous vein.

Laboratory Note.—Write a note on the method of tracing the course of the lateral cutaneous vein.

The Gills and their Vascular Supply

Fix the fish on its back on the dissecting board. Turn the head towards you; you will find it more convenient. Remove only the skin from the whole of the ventral side of the head from the pectoral girdle to the mouth and laterally to the ventral ends of the gill clefts. Take care that no muscle is removed with the skin; this is much more easily done by using only the back of a scalpel while seizing the edge of a median incision with strong forceps or with the fingers.

When the skin has been removed, you will have exposed a thin sheet of muscle which covers the whole of the ventral

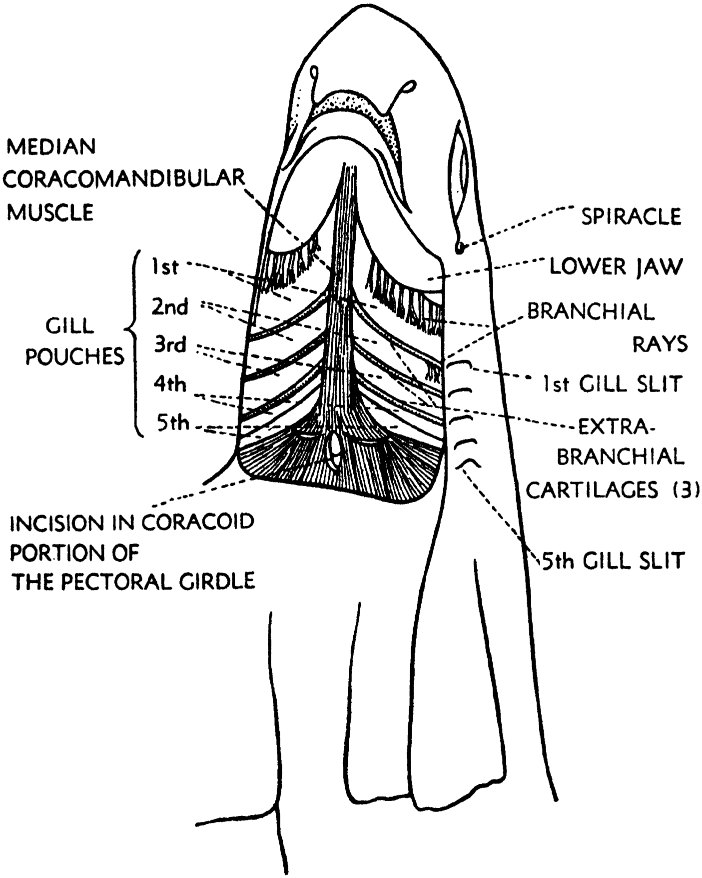


Fig. 35.—Dissection to show relation of gill pouches with gill clefts. Latero-ventral view.

branchial region thereby forming on each side a covering for the five gill pouches. The fibres of this **superficial branchial muscle** are disposed transversely. In addition to this sheet, note the end of a median longitudinal muscle

attached to the girdle; this will be found to run forwards beneath (dorsal to) the superficial branchials to the lower jaw. On each side of the pericardial cavity the exposed muscles will be seen to be directed towards the pectoral fins.

From now onwards it will greatly facilitate dissection if a glass specimen tube or a cylindrical piece of wood, about 3 in. by 1 in. ($7\frac{1}{2}$ cm. $\times$ $2\frac{1}{2}$ cm.) is pushed into the mouth to raise the floor of the buccal cavity and pharynx. The glass or wooden object is preferable to a wad of paper, being cleaner and more easily handled.

Next make a shallow median longitudinal incision with a scalpel, not more than $\frac{1}{8}$ inch deep to avoid the danger of involving the underlying muscle, and carefully peel off the superficial branchial muscles completely. This needs care to avoid cutting into the gill pouches on each side. The operation should result in exposing a median longitudinal muscle, the **coraco-mandibular muscle**, the end of which you have already seen at the pectoral girdle. This muscle shows distinct signs of a paired origin, but the halves are so closely united as to constitute a single median muscle.

Gill Pouches

On each side the membranous **gill pouches** will be exposed; these contain the gills. A complete study necessitates a careful examination of these, and for this reason the pouches should remain intact for the time being. The first four will be easily recognised, but the fifth may be less obvious. The gill pouches become successively smaller from the first to the fifth, and to expose the last the edge of the basal muscles of the pectoral fin must be bared, after which you will see the gill pouch lying close to the muscle. Insert a seeker into each gill cleft and notice that it enters the corresponding gill pouch. The adjacent walls of successive gill pouches constitute the **interbranchial septa.** At the ventral edge of each interbranchial septum except the fourth, *i.e.* between pouches 1 and 2, 2 and 3, and 3 and 4, will be found a slender curved cartilage called the **extrabranchial cartilage.** If these cartilages are not immediately visible, a little scraping will reveal them.

Each extrabranchial cartilage is held in position by a vertical sheet of muscle in the interbranchial septum. Remove the first cartilage by severing its muscle attachment, and study its form.

It is easily possible to separate each gill pouch from its neighbour by breaking down the connective tissue binding the membrane of the pouch from the sheet of muscle in the septum. Examine the anterior face of the first gill pouch by separating it from the ceratohyal cartilage which is immediately in front of it and mostly hidden by the lower jaw. This will enable you more easily to note the delicate **branchial rays** in the membranous wall of the pouch. They are present in the anterior wall of each of the gill pouches, but are most easily demonstrated in the first. Here they are multiramous, *i.e.* they branch at their ends into two or more, but in each of the other pouches they are uniramous, being unbranched. They are attached to the ceratohyal and ceratobranchial and epibranchial cartilages.

The first afferent branchial artery will be seen clinging close to the anterior wall of the pouch, and branches from it can be seen alongside the branchial rays.

Make an incision along the middle of the ventral wall of a gill pouch, continuing the cut to include the corresponding gill slit. Completely separate the walls of the pouch, and looking inside from the gill slit you have a complete lateral view of the interior of the gill pouch. The gill lamellae are present on each side of the pouches, except the fifth, which has them only on the anterior face and is therefore called a **hemibranch.** The gills on each side of the other pouches constitute a **holobranch.**

The internal opening to the pharynx is seen to be bounded by two successive ceratobranchial and epibranchial cartilages—or in the case of the first pouch, by the ceratohyal in front and the first cerato- and epi-branchial behind—their curves directed outwards and backwards. Radiating from the curvature of the cartilages are the **gill lamellae,** longitudinally arranged and attached to the walls of the pouch throughout except at their extreme distal ends. Along the axis of each lamella the **gill filaments** are

arranged at right angles. They are closely set and appear almost like the leaves of a book. The gill filaments are highly vascular, as can be seen, in a fresh specimen, by their red colour. Here are found blood capillaries which are thus brought into close relation with the current of water passing through the pouch from the pharynx to the gill slit.

Along the whole length of each lamella you will see the pale coloured axis in which is a blood vessel carrying aerated blood from the gill filaments. At the base of the gills these vessels join an arterial collecting loop, which runs the whole length of the cerato- and epi-branchial cartilages on each side of the gill pouch. This vessel is the **efferent branchial loop,** which at the dorsal end of each internal gill cleft is continuous with an **epibranchial artery** in the roof of the pharynx. On each side four such epi-branchial arteries join the main artery of the body—the **dorsal aorta.** (See Fig. 40, p. 117.)

In the septa between the successive gill pouches lie the **afferent branchial arteries,** one along each of the five gill arches. Branches from each side of these afferent vessels pass up the walls of the gill pouches to take deoxygenated blood to the gill filaments.

Such, then, are the respiratory organs of the dogfish. We shall now proceed to expose the ventral aorta and the afferent branchial arteries arising from it. With few exceptions respiration by gills and lateral gill clefts is not found in any other group than fishes.

Afferent Branchial Arteries. Now return to the middle line. Separate the coraco-mandibular muscle from the underlying structures by blunt dissection, so that it is free throughout its length. Then remove it by first cutting across it near its origin at the pectoral girdle; then peel it off forwards and cut it across at the lower jaw. Immediately beneath (dorsal to) the coraco-mandibular muscle you will find a pair of longitudinal muscles called the **coraco-hyoid muscles.** If you pull these muscles you will find, on opening the mouth, that they depress the tongue

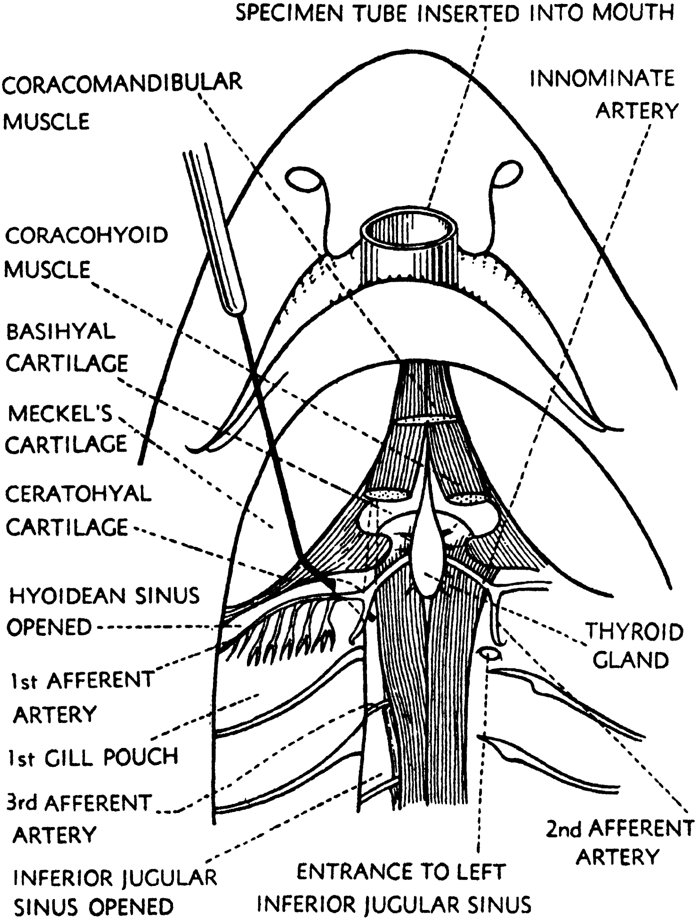


Fig. 36.—Dissection to show relationship between the hyoidean and inferior jugular sinuses. The seeker is passed through the junction of the two sinuses. On the left of the figure, the right inferior jugular sinus has been opened.

because they are attached to the basihyal cartilage, which supports the tongue. By parting these muscles at about the level of the posterior edge of the mandibular cartilages, or half-way along the muscles, you will find a small oval pear-shaped or rhomboidal body (the shape varies with the action of the preservative), which is the **thyroid gland.** It is usually pinkish if fairly fresh, or slate-coloured if long preserved, and about $\frac{3}{16}$ or $\frac{1}{4}$ inch (about 6 mm.) long. Remove the coraco-hyoid muscles as you did the coraco-mandibular.

You will probably find that a quantity of blood or blood clot will be encountered round the thyroid, for you will have entered an irregular blood space or anastomosis which communicates with the inferior jugular sinus. By dissecting carefully round the gland with the back of a scalpel so as to loosen it, the thyroid may be moved to one side, or removed altogether. Beneath (dorsal to) it will be found the anterior division of the ventral aorta into right and left **innominate arteries.** [*Note.*—The innominate artery and its branches are sometimes hidden by connective tissue which, with care, is easily removed.]

The branching of the innominate artery on each side to form the first and second **afferent branchial arteries** is now easily followed. The second afferent vessel can, as yet, be traced only for a short distance. Close to the place where it disappears, you will see a prominent circular opening. This opening leads to the **inferior jugular sinus.** Direct a seeker into this aperture in a posterior direction, fairly deeply, and you will find that it passes very readily as far as the pericardium. Across the dorsal wall of the sinus lie afferent blood vessels, and the seeker must not pass under them. Having felt your way, withdraw the seeker to the entrance and re-insert it, keeping it well up and in contact with the *ventral* wall (uppermost in the dissection) of the sinus and not so deep as to touch the dorsal wall. With the seeker inserted to act as a guide, open up the sinus in a posterior direction only, and keep the lower blade of the scissors well up when cutting because you must cut only the ventral wall of the sinus. Still

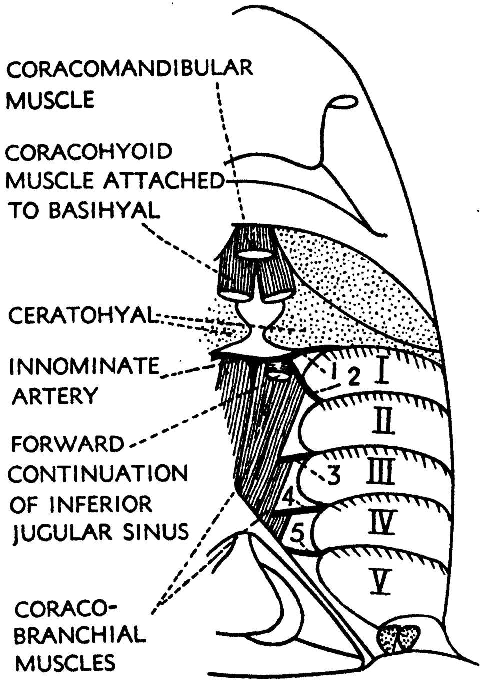


Fig. 37.—The left inferior jugular sinus opened.
1-5, afferent arteries.
I.-V., gill pouches.

with the seeker acting as a pilot, follow the sinus along the side of the pericardium right to the Cuvierian duct. Throughout, be careful to follow the seeker accurately and cut slowly, always *above* the seeker.

With great care so as not to cut through the innominate artery, open the sinus forwards only as far as the innominate and no farther. A seeker can now be inserted forwards, under (dorsal to) the innominate artery, to demonstrate that the inferior jugular sinus continues forward as a much narrower vessel.

Return now to the first afferent branchial artery where it runs round the first gill pouch. Immediately in front of it, and parallel with it, is the **hyoidean sinus,** whose opening into the anterior cardinal sinus, above the gill pouches, you have seen. You may possibly see the blood moving in the sinus. The hyoidean sinus passes just beneath (dorsal to) the place where the innominate forks into the first and second afferent branchial arteries (see Fig. 36). Open the sinus up to the place where it passes under the first afferent branchial artery, and then direct a seeker as shown in Fig. 36 and note that it appears in the inferior jugular sinus. It is thus clear that the hyoidean sinus connects the anterior cardinal sinus with the inferior jugular sinus. It is quite an easy matter to follow the vessel by dissection to the anterior cardinal sinus, and in this way to verify the opening at the anterior end of the anterior cardinal sinus.

Next examine the inferior jugular sinus. At the bottom of it as you examine it—really, of course, in the roof of the sinus—you will see the third, fourth, and fifth afferent branchial arteries crossing to the gill pouches. If you do not immediately see them, search with a blunt instrument such as a seeker to break down any connective tissue which may tend to mask the vessels. By this dissection you at once become acquainted with the depth of the afferent vessels, and should be able to trace them throughout without cutting them.

Before the afferent vessels can be fully exposed and seen to originate from the ventral aorta, the successive series of longitudinal muscles, or **coraco-branchial muscles,** attached to the hypobranchial cartilages, will have to be removed close to their attachments. Fig. 37 shows how these muscles are arranged in relation to the arteries. The function of these muscles is interesting. You will remember that the coraco-mandibular muscles are attached to the lower jaw, and therefore by contraction they will help to open the mouth. The coraco-hyoid muscles, you will also remember, are attached to the basihyal cartilage, and when they contract depress the tongue. Similarly, the coraco-branchial muscles, attached to the hypobranchial cartilages,

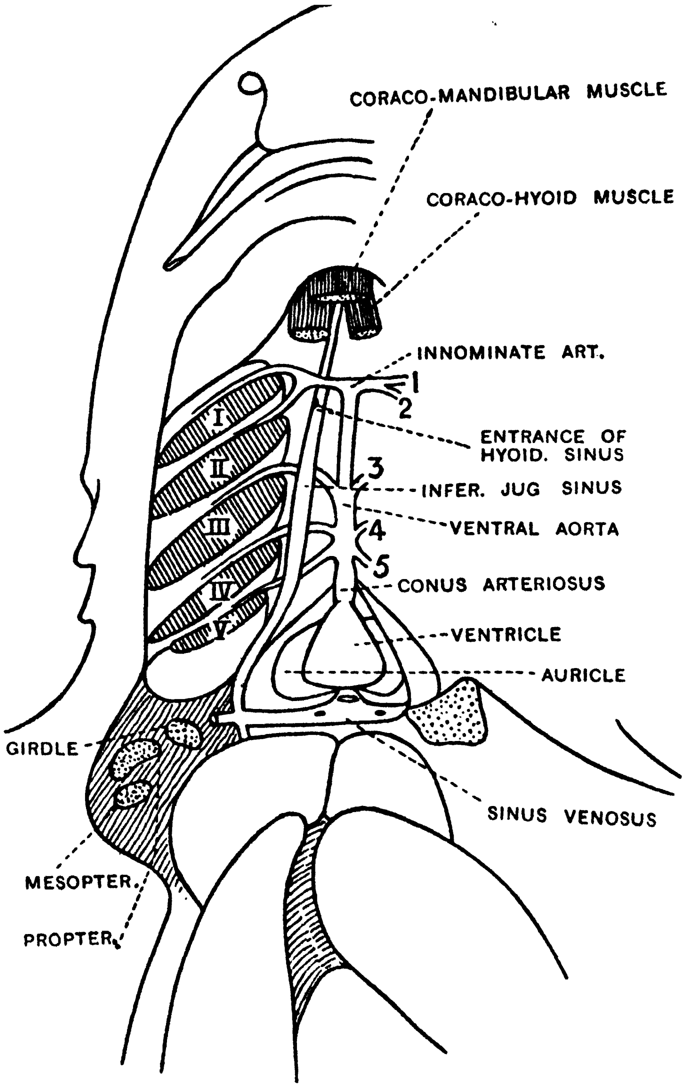


Fig. 38.—Relation of the inferior jugular sinus to the afferent branchial arteries.

1-5, afferent branchial arteries. I.-V., gill pouches.

on contraction will draw the cartilages back and downwards. The total effect will be to open the mouth and enlarge the buccal cavity and pharynx for the incoming current of water. The superficial branchial muscles will have the opposite effect of reducing the capacity of the pharynx and expelling the water through the gill clefts.

In each case before actually removing each coraco-branchial muscle in turn, see that it is entirely free from any attachment beneath at the place where you insert the scissors. Starting with the uppermost (*i.e.* the ventral-most), cut across each muscle anteriorly as closely as you can to the vessel under (dorsal to) which it passes, and peel it off backwards free of the succeeding afferent vessels it covers. This will also expose the **ventral aorta** itself in the middle line. The complete dissection should show the ventral aorta as a continuation of the conus arteriosus, and the five afferent branchial arteries passing the whole length of the gill pouch. To do this, place the back of the small scalpel alongside each artery and cut upwards through the tissue lying over the vessels. In this way expose the arteries along their whole length. The pouch should then be cut away to the level of the artery and the gill filaments trimmed off as closely as possible, so that the artery becomes fully exposed.

Drawing.—Make a drawing to illustrate your dissection of the afferent branchial arteries. Indicate also the relationships of the inferior jugular and hyoidean sinuses to these arteries.

Laboratory Note.—Write a laboratory note on the method you adopted to expose the afferent branchial vessels.

Dissection of the Heart

Make a longitudinal incision along the ventral middle line of the ventricle, and then remove completely the ventral wall, so that the interior of the ventricle may be seen. Continue the median incision along the conus arteriosus, and wash out the contents of both ventricle and conus. Pin back the walls of the conus. Note (1) The strongly muscular nature of the wall of the ventricle and

the ridges of muscle forming longitudinal pillars called **columnae carneae.** (2) The **auriculo-ventricular aperture**, a large opening slightly to the left of the middle line and in the dorsal wall of the ventricle. Pass a seeker through the aperture, and note that it will pass readily to either side without obstruction; this makes it clear that the auricle is a single chamber. (3) The presence of two rows of three **valves** in the conus arteriosus. The form of the valves differs in each case. The posterior row consists

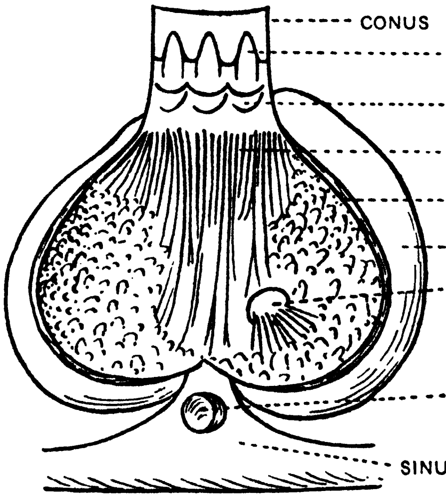


Fig. 39.—Dissection of the ventricle and conus of the heart.

of three simple pocket or semilunar valves, so arranged as to prevent backward flow of blood to the ventricle. The valves in the anterior row are also three in number; each consists of a narrow, elongated, fleshy tongue with a membranous wing on each side attached to the wall of the conus. The action of these valves is similar to that of the semilunar valves behind them.

Drawing.—Make a drawing to show the interior of the ventricle and conus arteriosus. Indicate the muscular nature of the walls of

the ventricle, the auriculo-ventricular aperture, and the valves of the conus arteriosus.

THE PERICARDIO-PERITONEAL CANAL. On page 94 reference was made to this passage as forming a communication between the two coelomic cavities, viz. the pericardial and the peritoneal or perivisceral cavity. It may now be examined by raising the dorsal wall of the sinus venosus so as to get completely dorsal to the heart—indeed, since you have finished your study of the heart, the sinus may be cut across near the sinu-auricular connection. The pericardial entrance to the canal will be seen as a large aperture in the middle line, and a seeker should be passed into it and its appearance in the perivisceral cavity noted. You will see that it appears close along the ventral wall of the oesophagus.

Laboratory Note.—Write a note in your laboratory note-book describing the position of the pericardio-peritoneal canal and how you demonstrate it.

The Epibranchial Arteries

You have seen that the ventral afferent arteries take the deoxygenated blood forward to the gills for oxygenation. In order to make clear the relationships between the afferent system, the gills, and the efferent system, a purely diagrammatic representation is given in Fig. 40.

Each of the five afferent vessels passes along a gill arch in the septum between two gill pouches. The blood so brought to the gills is collected by a loop which encircles the gill cleft, and each half of a loop is called an **efferent branchial artery**, which is thus situated along the side of a gill arch. In each of the first four branchial arches (I. to IV. in the diagram) will be found an afferent and two efferent branchial arteries. In the hyoid only one efferent accompanies the afferent vessel. Since the fifth gill pouch contains only a hemibranch, there is no loop, but a single efferent artery which, by its anastomoses, communicates with the posterior half of the preceding loop.

At the dorsal end of each of the first four gill clefts, an **epibranchial artery** collects the blood from each loop. The

epibranchial arteries from each side join the dorsal aorta which runs in the middle line throughout the body.

The first step in dissection is the exposure of the four epibranchial arteries. These vessels lie beneath the mucous membrane of the roof of the pharynx. To expose the roof, put the large scissors in the angle of the mouth and cut parallel with the side of the body through the lower jaw and branchial arches, making sure that all the branchial arches are cut through. The incision will now have reached the region of the septum separating the pericardial cavity from the body cavity. At this point cut

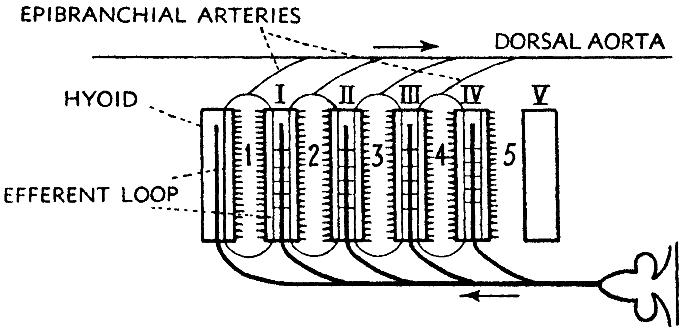


Fig. 40.—Diagrammatic representation of the circulation in the branchial region of the left side of the dogfish.
1-5, gill clefts; I.-V., branchial arches.

transversely immediately behind the septum, taking care in both sexes not to damage the anterior parts of the reproductive system. If the pericardium has been opened properly, the incision will pass underneath (dorsal to) the the cut end of the pectoral girdle, and the fin will be quite free. The floor of the buccal cavity and pharynx may now be turned over and fixed to the dissecting board by an awl through the basihyal.

With a sponge thoroughly clean the mucus from the roof of the pharynx and buccal cavity, and the courses of the four epibranchial arteries can usually be seen through the

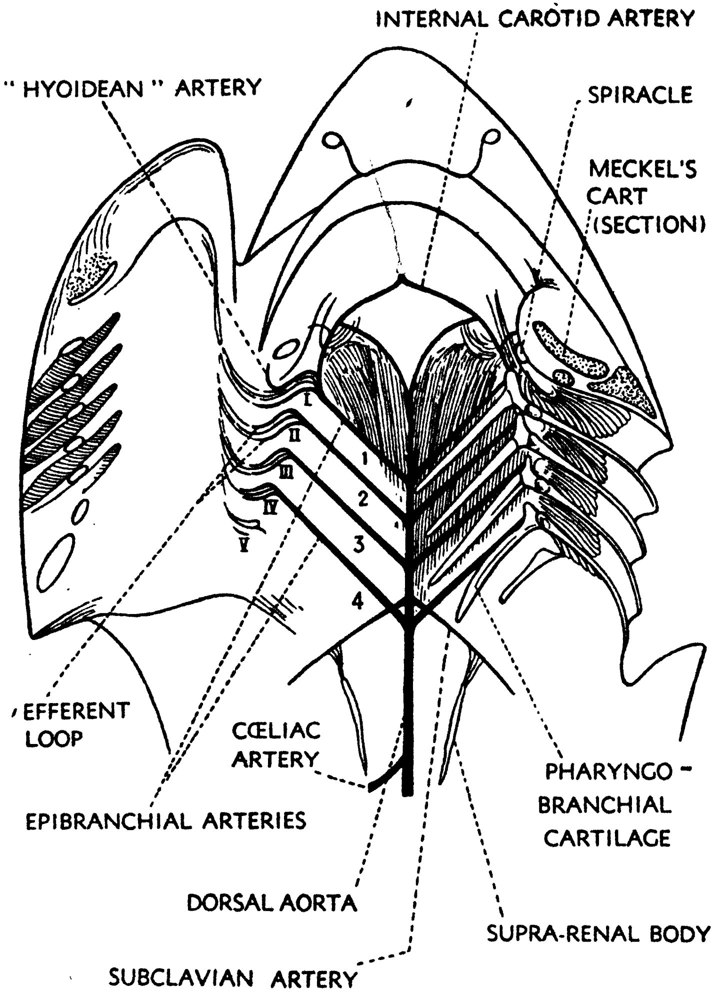


Fig. 41.—The epibranchial arterial system. On the right of the figure the pharyngobranchial and epibranchial cartilages are still in position; on the left they have been removed, the union of the first pair of pharyngobranchials having been cut.

mucous membrane which covers the surface of the pharynx and buccal cavity. The mucus produced by the glands of the mucous membrane is usually plentiful, especially in fresh specimens, and with good reason. The dogfish, we have said, is voracious and bolts his food; the mucus therefore is necessary as a lubricant to assist in swallowing the prey.

The first epibranchial artery on each side passes from the first gill cleft diagonally backwards to the middle line to the dorsal aorta. The remaining three on each side run parallel to the first. You will now have a landmark to indicate where particularly careful dissection is needed during the next operation of removing the mucous membrane from the roof of the buccal cavity and pharynx.

Begin the dissection by making a short transverse incision about ½ inch (1¼ cm.) through the mucous membrane close to the upper jaw. From this incision, bit by bit, cut backward in the middle line throughout the length of the pharynx, and at the same time work outwards towards the sides of the pharynx, making sure that you remove nothing else but mucous membrane. In preserved specimens the mucous membrane usually comes away very readily. As you approach the first pair of epibranchial arteries special care is necessary to avoid cutting the vessels or removing them with the mucous membrane. Continue until all four pairs of vessels are exposed, and cut off the flaps of mucous membrane along the sides of the pharynx. To reveal the union of the fourth pair with the dorsal aorta, it will be necessary to loosen the attachment of the dorsal wall of the oesophagus which was cut across when making the preliminary transverse incision.

When all the vessels have been exposed, further dissection must be undertaken to free them from surrounding tissues. Between the vessels will be found the **pharyngo-branchial cartilages.** The first pair of these meet and fuse in the middle line over (ventral to) the dorsal aorta, and the first pair of epibranchial arteries lie close along their anterior margins. If the pharyngo-branchial cartilages are insufficiently distinct, a little careful scraping will be an advantage.

Take a sharp scalpel, held with its back towards the dorsal aorta, and insert its point beneath the union of the first pair of pharyngo-branchials and, with an upwardly directed cut, divide them. Then clearly ascertain the course of the first epibranchial artery on one side, and free it by carefully dissecting it away from the cartilage along its whole length, using the point of a small scalpel held back downwards, raising the vessel with the forceps as you proceed. When the vessel is freed, raise the cartilage with the forceps at its severed end and free it from its underlying attachment. Continue the process until the gill cleft is reached, at which point the cartilage can be cut through and removed. Do the same dissection on the opposite side.

At the dorsal end of the gill cleft, the pharyngo-branchial cartilage is joined to the **epibranchial cartilage**, the next in the series constituting the branchial or gill arch. This cartilage forms the angle in the arch at the dorsal end of the gill cleft and continues a short distance between the neighbouring gill clefts before it joins the **cerato-branchial cartilage.**

In order easily to see the union of the halves of the efferent loop to form the epibranchial artery, raise the epibranchial cartilage, and the union of the vessels will be seen beneath. To display the efferent loop, free the epibranchial cartilage on all sides and cut it away.

The same procedure should be adopted for each of the other pairs of epibranchial arteries except that, since the remaining pairs of pharyngo-branchial cartilages are not united in the middle line, there is no question of separating them from one another. Each efferent branchial artery should be followed for a short distance along the branchial arch and clearly displayed.

Unfortunately, there appears to be no unanimity among authorities concerning the names of arteries supplying the anterior part of the head. The confusion has been brought about (1) *by the misinterpretation of homologies, and* (2) *by the considerable variations met with among Elasmobranchs. The names adopted here have been chosen after consideration of the findings of recent researchers, and with a desire to keep*

the nomenclature simple enough to avoid confusion by the elementary student.

Just before the anterior and posterior efferent branchial arteries of the first gill pouch join to form the first epibranchial artery, the anterior efferent gives off a branch artery which passes forward, describing an arc to the middle line, where, with its fellow of the opposite side it enters the cranium to supply the brain. It appears desirable to describe the whole of this vessel as the **internal carotid artery.** Its anterior part is universally recognised as the internal carotid, but a branch[1] which passes outwards just anterior to the spiracle is frequently wrongly described as the external carotid artery—which artery really leaves the ventral end of the first efferent loop—and consequently the part from the first efferent to the branch mentioned was called the common carotid artery. Thus since the name common carotid was applied in error, it would appear simpler to consider the whole vessel as the internal carotid artery. The internal carotid is, in reality, always a forward continuation of the dorsal aorta, but since in some Elasmobranchs the forward continuation does not reach the lateral vessel, it cannot be called internal carotid.

The continuation, forward, of the dorsal aorta consists of a single vessel which very soon divides to form two diverging branches. These are not always easy to see, as they contain little blood. In order to trace them, all connective tissue needs to be removed. Their courses lie in shallow grooves on the ventral side of the chondrocranium from the junction of the two first epibranchial arteries, curving outwards to join the internal carotid artery.

This forward continuation is clearly a vessel of no great importance in the adult, and it contains very little blood. One can see that if the supply of oxygenated blood to the brain depended on this forward continuation, the brain would be very inadequately supplied; but by having a direct connection with the first efferent artery, the internal

[1] Called the stapedial artery by O'Donoghue.

carotid artery is able to satisfy the demands of the brain in this respect.

The first efferent branchial artery—the anterior half of the first efferent loop—gives rise also to another artery forwards. This is the " hyoidean "[1] which leaves the first efferent artery half-way along the gill arch and quickly disappears through deeper muscles to pass to the outer side of the spiracle. It then enters the orbit (see page 49 and Fig. 53). The artery is a difficult one to dissect out completely, and unless ample time is available it is suggested that you should remain satisfied with the examination of the portion seen in the orbit.

Before leaving the epibranchial arteries, attention should be directed to the **subclavian arteries**, one of which arises from the dorsal aorta on each side between the unions with the aorta of the third and fourth epibranchial arteries. On its way to the pectoral fin, it gives off a branch which runs posteriorly, called the **lateral artery**, and on arriving at the base of the fin it divides into the **brachial artery** to the fin itself and a **ventro-lateral artery** to the body wall.

If the epibranchial arteries have been dissected so as to stand out clearly from all surrounding tissues, it is most likely that a series of nerves will have been noticed. These will be the IXth and branchial branches of the Xth cranial nerves, all of which fork so as to supply each side of a gill pouch. In addition, you may notice other, somewhat smaller, nerves issuing from near the middle line. These are spinal nerves. The more anterior ones converge to accompany the main trunk of the Xth cranial nerve backwards, and eventually curve ventralwards and supply the hypobranchial muscles. The more posterior ones anastomose to form the brachial plexus of nerves at the base of the pectoral fin.

[1] The name " hyoidean " has been commented upon by recent researchers and regarded as unsatisfactory in that it does not supply the hyoid. Some have called it afferent pseudobranchial, and O'Donoghue prefers that it should be called the afferent spiracular as far as the spiracle, and beyond the spiracle, spiracular epibranchial artery. We have retained the name hyoidean, but in quotation marks, merely on the grounds of most frequent usage and simplicity; but the objection to the name will now be apparent.

A short distance behind the last epibranchial arteries, you will see, arising from the dorsal aorta, the **coeliac artery,** the median vessel whose branches to the liver, alimentary canal, and gonads you have already studied. To expose its origin, you will find it necessary to dissect away the dorsal attachment of the oesophagus and remove a plexus of nerves covering it. About an inch (2·5 cm.) farther back, you will find the origin of the **anterior mesenteric artery** closely followed by the **lienogastric artery,** both of whose courses to the alimentary canal you have traced. Throughout the abdominal region the dorsal aorta gives off a regular series of **segmental arteries** to the body musculature.

Drawing.—Make a drawing to illustrate your dissection of the epibranchial arterial system, including the efferent loops, the internal carotid artery, and any other vessels you have been able to trace.

Laboratory Note.—Write a laboratory note explaining the procedure adopted in exposing the epibranchial arteries.

THE RENAL AND REPRODUCTIVE ORGANS

For the dissection of the urinogenital system the alimentary canal must be removed. If the pelvic girdle has not already been cut through, with a scalpel make a clean cut through it so as to divide it into two equal halves. It will then be quite possible to cut down from the surface in the middle line through muscle only, as far back as the cloacal groove, and expose undamaged the floor of the cloaca. It is worth attempting, as it gives you a more complete idea of the form of the cloaca when you have seen it intact. If you succeed, make a drawing of your dissection. After making this record, cut along the middle line of the cloaca floor and expose the cavity fully. If you do not succeed in preserving for a time the floor of the cloaca, you should remember that the floor has been cut through, and reconstruct the form. Fix the pelvic fins to the dissecting board so as to keep the cloacal cavity fully exposed.

NOTE.—*Read through the whole of the following paragraph before undertaking any further dissection.*

Cut across the rectum quite close to the cloaca, then sever the mesentery, which holds the alimentary canal in place, throughout to the oesophagus. Cut across the oesophagus close to the stomach; this is especially necessary in the female in order to avoid damage to the oviducts which join on the ventral side of the oesophagus. In the *female*, if the ovary is large it should be removed by cutting through the mesovarium. Should the removal be necessary, make a note at once of the size, position, and condition of the ovary. In the *male*, be sure to handle the testes with care, for, especially in fresh specimens, they are easily dislodged, particularly at their anterior ends; it is most necessary to keep the anterior attachment intact so as to preserve the fine ducts passing from the testes to the Wolffian ducts. It will be noticed that there is no bladder. The absence of a cloacal bladder is a character of fishes, for it is found in all other vertebrates, if not in the adult, at least in the embryo, when it is called the allantois.

Dissection of the Female Organs

The ovary and the parts of the oviducts immediately visible on opening the body cavity have already been studied (p. 78), and it was emphasised that the appearance of these organs depended upon the sexual maturity of the fish. Now that the alimentary canal has been removed, the anterior ends of the oviducts can be seen. Follow the oviduct of one side forwards; on nearing the oesophagus it will turn inwards towards the oesophagus, on whose ventral surface it unites with its fellow of the opposite side. At the union is the single **oviducal aperture**, opening into the body cavity. This opening is large and in the form of a wide longitudinal slit, such as would be formed when two funnels are fused along half of their edges.

Released from the ovary, the eggs are shed into the body cavity and find their way to the oviducal opening to pass down the oviduct. At the shell, or **oviducal, gland**, each

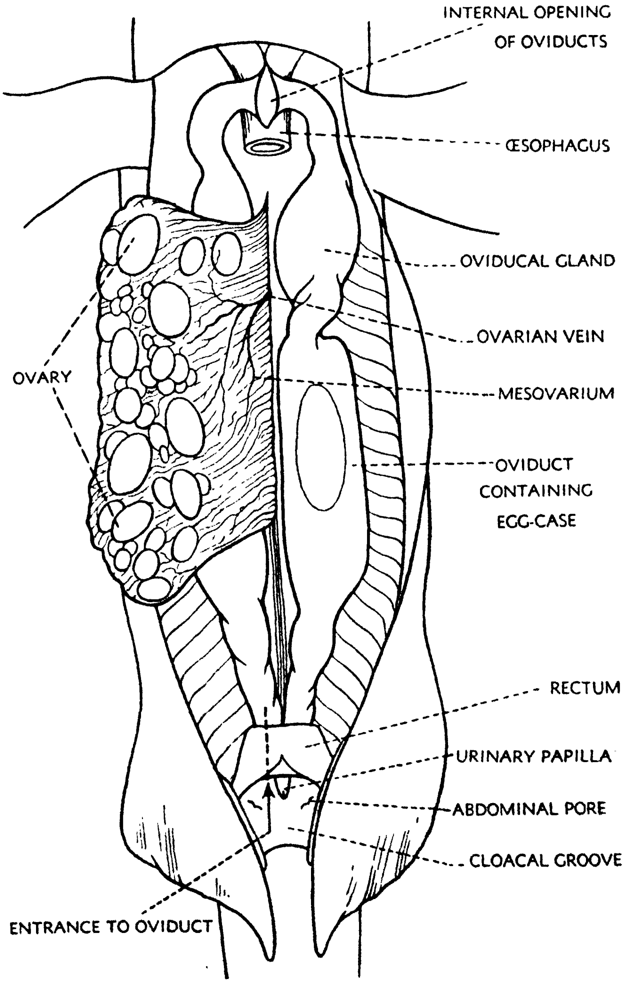


Fig. 42.—Female reproductive organs in a mature specimen.

egg receives its case; this is a rectangular horny structure, whose corners are drawn out into long, closely coiled, tendril-like processes which, on deposition, enable the "mermaid's purse," as it is called, with its developing embryo, to be anchored safely to weeds. Normally, towards its end each oviduct widens considerably, but when an egg in its case is present in the middle part, it

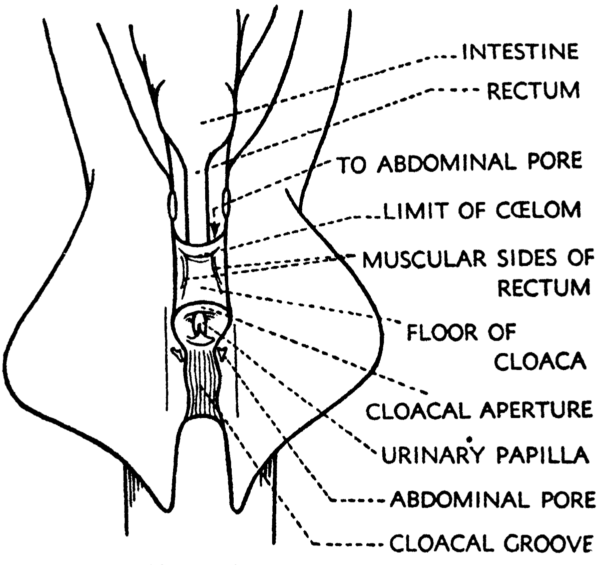


Fig. 43.—Cloaca of a young female dogfish intact.

obviously causes an abnormal distention of that part. You will now proceed to examine the posterior termination of the oviducts.

Having separated the pelvic girdle into two halves, and cut backwards to the cloacal groove through the ventral wall of the cloaca, you will have the dorsal wall in view.

There is a notable difference between the mature and the young female dogfish in the anatomy of the cloacal

region. This is due to the presence in the immature fish of the **hymen**, and its absence in the older fish.

In mature females, as soon as the floor of the cloaca has been cut along its middle line, the terminal openings of the oviducts are seen, one on each side of the urinary papilla. Each oviduct opens independently into the cloaca, the two being separated by a delicate membrane extending from the middle of the urinary papilla to the floor of the cloaca. A seeker may at once be inserted into each of the oviducts.

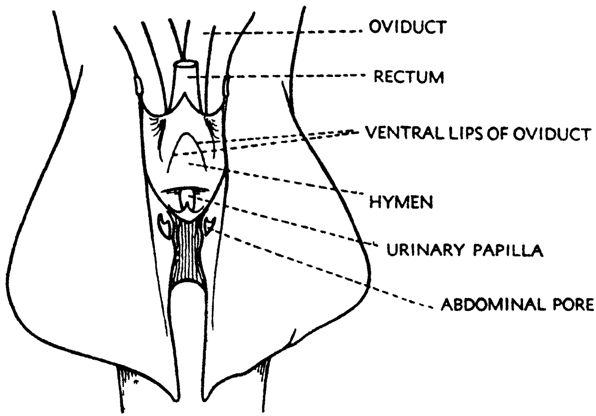


Fig. 44.—Young female dogfish, cloacal floor opened.

Things are very different in the young immature female, apart from the smaller size of the oviducts. On cutting open the floor of the cloaca, you will expose a chamber into which, anteriorly, the rectum enters, and at the posterior edge the urinary papilla opens. This chamber must be regarded as a cloaca, since the waste products are received there prior to their expulsion. But you can see no entrance to the oviducts. In the body cavity find the oviduct of one side and make a small slit in it. Into the slit pass a seeker, directing it backwards towards the cloaca. You will see the end of the seeker pressing against

the membranous roof of this cloacal chamber. This membrane, which stretches from one side to the other, is the hymen, and it effectively closes all communication between the oviducts and the outside.

Drawing.—If your specimen is an immature female, make a drawing of the cloaca with the hymen indicated. Show the opening of the rectum into it and the position of the urinary papilla.

Laboratory Note.—Write a short note on the presence of the hymen and its position in immature females.

In the young female, first wash out the cloaca thoroughly, and you will then clearly see the position of the lips of the oviducts making a more or less conical outline. The area between the lips of the oviducts is the hymen to be removed.

The removal of the hymen exposes a dorsally situated chamber into which the two oviducts open. This chamber may be called the **genital sinus.** Insert a seeker into each

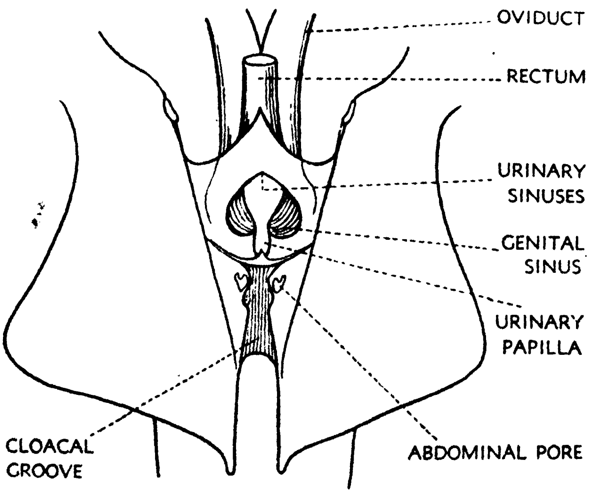


Fig. 45.—Cloaca of young female dogfish with hymen removed.

oviduct. In the middle of the genital sinus is the muscular base of the urinary papilla, in which are the posterior ends of the urinary sinuses.

Comparing the anatomy of the mature and immature female, it will be clear that the cloaca of the mature fish is really a double chamber, viz. cloaca and genital sinus, united by the breakdown of the hymen. In the young female these two chambers are separate, but, of course, the genital sinus is, during immaturity, functionless.

It is worth while remarking that an intermediate stage is not infrequently met with. In such cases it will be found that the breakdown of the hymen is only partial, a slit having appeared along its posterior attachment. In this condition, the cloaca proper and the genital sinus are two separate chambers, each with its own opening into the cloacal groove.

Drawing.—Make a complete drawing of the female reproductive organs, including the internal opening of the oviducts, the oviducal or shell glands, the whole of the oviducts, and the dissection of the pelvic region showing the termination of the oviducts and neighbouring structures. The drawing should be made inside an outline of the body.

The dissection of the **urinary system** in the female is often unsatisfactory. The reason is that the urinary sinuses are so closely attached to the dorsal walls of the oviducts that it is practically impossible to separate the two sets of structures. The best plan is to insert a seeker into the urinary aperture and, with small scissors, to cut along the ventral wall so as to lay open the cavity for about $\frac{1}{2}$ to $\frac{5}{8}$ inch (12 to 16 mm.) and no more. At about this place, the two urinary sinuses open side by side into the cavity of the papilla, but do not try to find the apertures yet. The walls of the sinuses are very delicate, and you can scarcely hope to cut down between the oviducts to expose them without cutting into one or both. Having laid open the papilla so far, insert a seeker, which will pass into one or other of the two sinuses, which are close together. The seeker will usually be seen in the sinus just in front of the closely approximated oviducts. Exploration with the

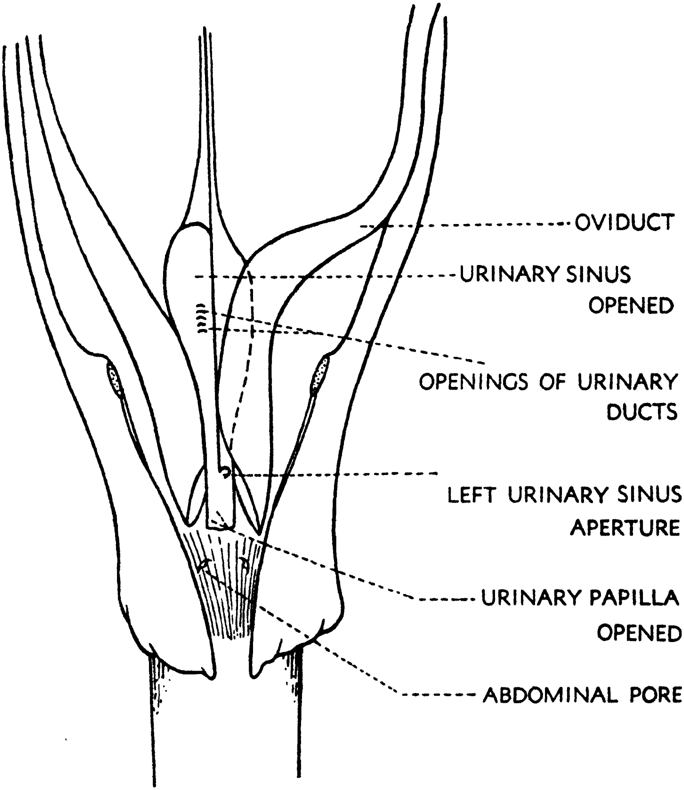


Fig. 46.—Dissection of the urinary sinuses in the female dogfish.

seeker will reveal the size of the sinus, which is considerable in width, rapidly tapering in front. Do not force the seeker; if you do, it is more than likely that you will puncture the wall and find you have penetrated the posterior cardinal sinus between the kidneys.

Knowing into which of the urinary sinuses you have passed the seeker, right or left, cut along the *outer* side of

the seeker and lay open the sinus; the operation will, at the same time, of course, separate the oviducts. Careful washing will reveal the openings of the kidney ducts on the side of the sinus next the kidney, *i.e.* its dorsal side. The openings, four or five in number, will be recognisable, with a lens, as minute transverse slits about half-way along the sinus.

Take the outer wall of the sinus in the forceps and, lifting it towards the middle line away from the kidney beneath, make a small incision with the small scalpel, in the peritoneal covering of the kidney, and remove it from the surface very carefully, remembering that you are hoping to display four or five delicate **ureters** which open into the urinary sinus by the slit-like apertures you have seen. When the surface of the kidney is exposed, the ducts, which converge towards the apertures, may be traced on its surface, the longest being the most anterior, which runs longitudinally along the kidney.

You will now be able to see the opening of the undisturbed opposite urinary sinus. Insert a seeker into the opening and explore the full extent of the sinus.

Drawing.—Make a drawing to show the position of the urinary sinuses, the ureters, and their internal openings.

The **kidneys** themselves are deep red organs when fresh, and brownish-red after preservation. They extend right to the posterior limit of the body cavity, dorsal to the posterior ends of the oviducts. In form they are a succession of lobes gradually diminishing in size forwards until they become vestigial. The functional part extends nearly two inches (4½ cm.), and the vestigial continuation reaches about half-way along the body cavity close to the dorsal wall. Posteriorly the two kidneys are in close contact dorsally, and between them ventrally is the beginning of the **posterior cardinal sinus**—here a single vessel which, on passing forwards from the kidneys, becomes divided by a septum into right and left posterior cardinal sinuses.

Remove the oviducts completely, and expose the whole of the kidneys, taking off any peritoneal covering. In

doing this, it is likely that you will also open the posterior cardinal sinus, which in any case must be done. You will know that the blood sinus has been entered, when you can

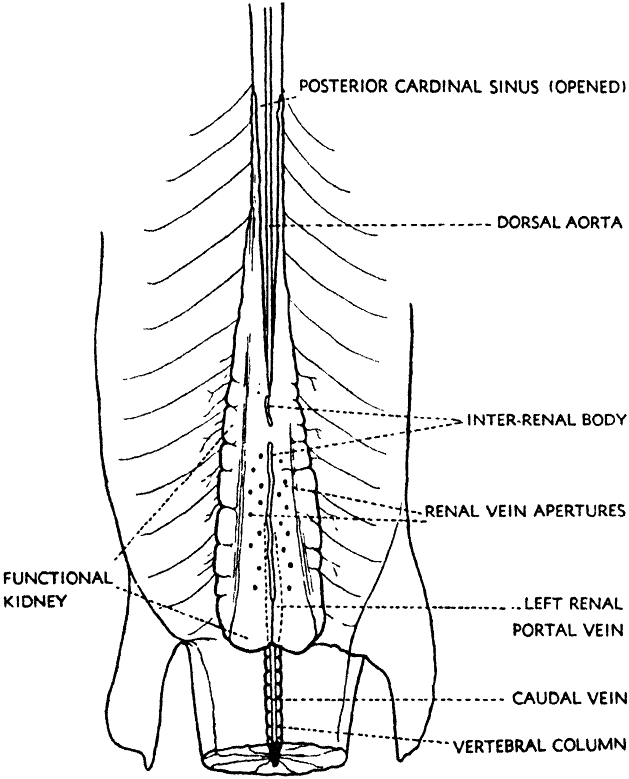


Fig. 47.—Dissection to show renal portal circulation.

see on the surface of the kidney many round apertures, which are the openings, into the posterior cardinal sinus, of the **renal veins.** These veins do not appear on the surface owing to the close relationship of the sinus to the

kidneys. There is no posterior continuation of the posterior cardinal sinus, since the vessel originates between the kidneys to take away the blood from the renal veins.

If you separate the kidneys, preferably with the fingers, in the middle line, you will find one long narrow body, and in front of it, a second shorter piece, bright red in fresh

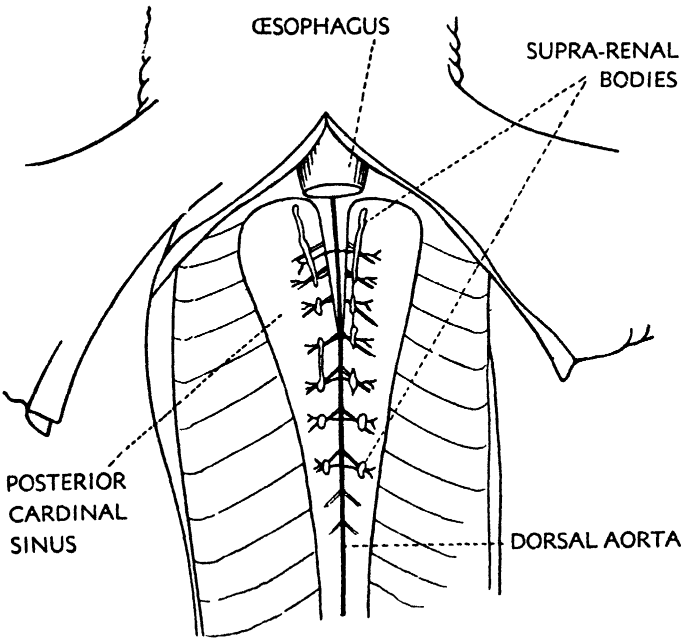


Fig. 48.—The supra-renal bodies of the dogfish.

specimens and commonly orange coloured in preserved. Each resembles a stretch of blood vessel gorged with blood. It is not a blood vessel, but a ductless endocrine gland called the **inter-renal body,** lying in the posterior cardinal sinus.

It will be well, while considering the inter-renal body, to look for other related endocrine glands called the

supra-renal bodies. They are seen in the opposite end of the posterior cardinal sinus. If you have not actually done so, remove all the viscera in the anterior end of the body cavity and also the ventral wall of the posterior cardinal sinus, so that you have a clear view of the anterior end of the dorsal wall of the sinus. In the position indicated in Fig. 48, on each side near the middle line, you will see a similar body to the inter-renal, pinkish in colour or, in animals long preserved, brown. Similar, but smaller, patches of the same gland are seen, more or less regularly placed on the small segmental blood vessels seen here. Together they constitute the supra-renal bodies.

It is interesting to note that these two separate endocrine glands—so important for the manufacture of hormones—are found, in the higher types of animals, compounded into single bodies known as adrenal bodies; the supra-renals represent the central part, and the inter-renal the outer part of the adrenal bodies.

Returning now to the kidneys and their vascular supply, it is clear that the renal veins only conduct away blood which has been brought to the kidneys by the renal arteries and the renal portal veins. The **renal arteries** enter the kidney direct from the dorsal aorta, and will not appear in the dissection. The **renal portal veins** are formed by the division of the caudal vein. You will recall that portal veins alone among the veins of the body branch after the manner of arteries. The **caudal vein** is contained in the haemal canal of the vertebrae of the tail along with, and ventral to, the **caudal artery** or continuation of the dorsal aorta.

With a large scalpel take off horizontal slices of the ventral muscles of the tail until you come to the cartilaginous vertebrae. Then proceed carefully so as to slice off the tips only of the haemal arches to expose the caudal vein. Open the vein and wash thoroughly, then follow it forwards to the posterior end of the kidneys, and with a seeker you will be able to pass either to the right or left of the middle line into either the right or left renal portal vein, which passes along the dorsal inner edge of the kidney.

Drawings.—1. Make a drawing of your dissection to show the position and extent of the kidneys in the body cavity, the renal vein openings, the renal portal veins, caudal vein, and the inter-renal body.

2. Make a drawing to show the position of the supra-renal bodies.

Dissection of the Male Organs

With great care turn the testes over to the right side so as to show the mesorchium of the left side supporting the left testis as in a sling from the mid-dorsal line. In the mesorchium, about 1¼ inches (3·2 cm.) from the anterior end of the vas deferens, you will see a blood vessel passing to the middle line; it is the **genital** or **spermatic vein** passing to the posterior cardinal sinus. The **spermatic artery** arises from the coeliac artery.

You have already become acquainted with the testes, mesorchia, vasa deferentia and vasa efferentia (page 79) and the siphon (page 71). It therefore remains to study the male ducts and their associated structures posterior to the vasa deferentia. As directed on page 123, you will have exposed the cloacal cavity. What little remains of the rectum will be sufficient to show its opening into the cloaca, and after noting this, it may be removed altogether.

The **urinogenital papilla** will now be clearly seen. It is in the mid-dorsal line of the cloaca, near the external opening at the cloacal groove. It is rather small and flattened from side to side. The urinogenital aperture at the end of the papilla is a longitudinal slit. Pass a seeker into the aperture. From your preparatory reading you will know that the seeker has passed into the **urinogenital sinus** formed by the union at their posterior ends of the two sperm sacs. The inserted seeker can be felt beneath the peritoneum.

The next operation is to strip off the covering of peritoneum from the urinogenital sinus and the ducts opening into it. To do this, make an incision in the middle line, in the peritoneum only, about half an inch (1¼ cm.) in front of the cloaca, and continue it forwards to about half-way along the coiled mass of vas deferens. Starting from the

front end of the incision, and with the seeker inserted into the sperm sac, seize the edge of the cut with the forceps and, by blunt dissection using the back of a scalpel, carefully separate the peritoneum from the underlying structures, and deflect the flap outwards. Special care is needed because the sperm sacs which are closely adherent to the

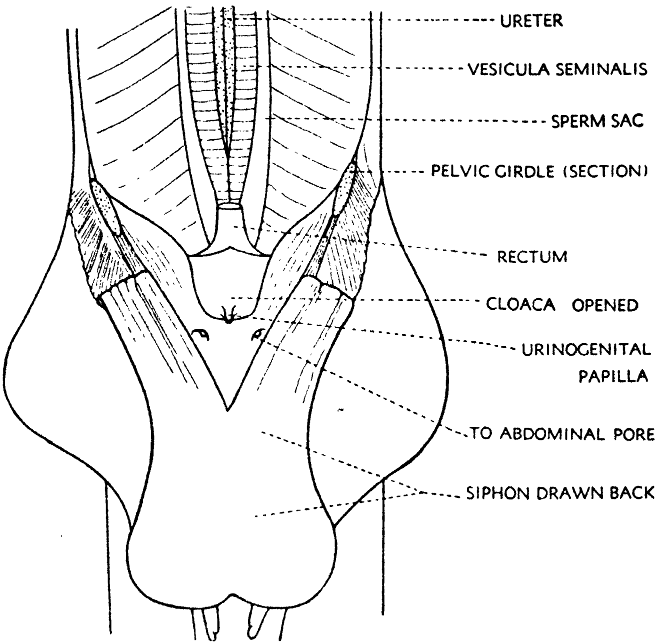


Fig. 49.—Male pelvic region with cloaca opened.

peritoneum are liable to be, in part, removed with it. After the removal of the peritoneum a certain amount of connective tissue will remain, giving a foggy appearance to the dissection; this should be very carefully picked off with fine forceps so that the ducts will stand out clearly. Parts of the ducts may now be identified.

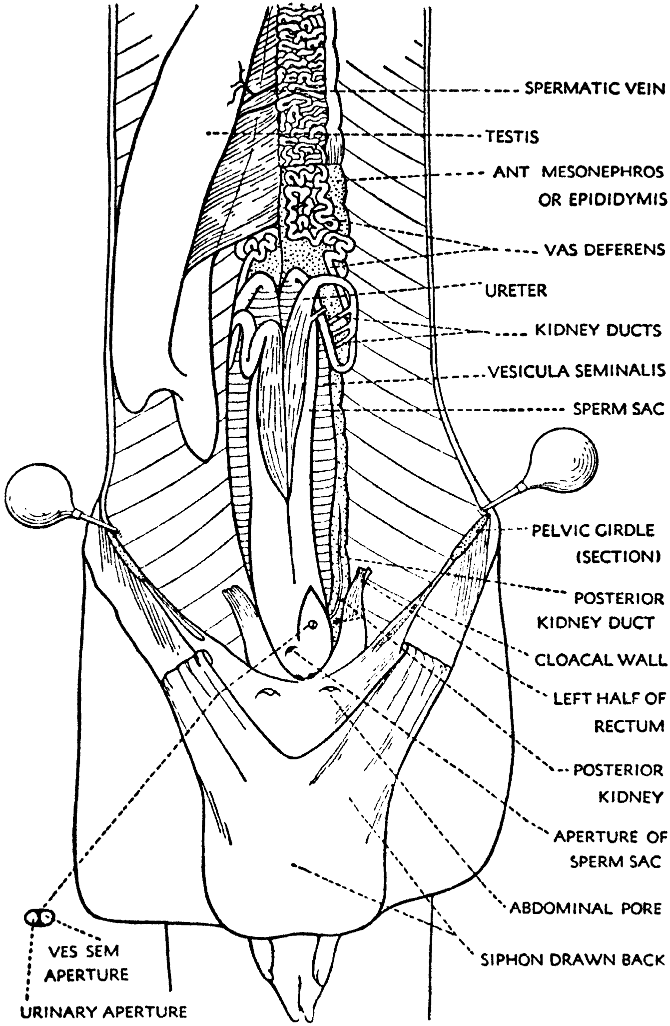


Fig. 50.—Dissection of the male urinary and reproductive organs. The rectum and urinogenital sinus opened, and the left sperm sac opened for a short distance. Apertures of the ureter and vesicula seminalis shown enlarged at the side.

On each side, the mass posterior to the closely coiled vas deferens is made up of (1) the vesicula seminalis, (2) the sperm sac, and (3) the ureter. The greater part of the **ureter** will be found near the middle line; it is a rather wide, soft, and flaccid tube, easily separated from adjacent parts. Its appearance seems to differ according to the maturity of the specimen. In mature adults it is of a dark brown colour, wide, and so shapeless as to be unrecognisable as a tube at first; further, the bends at its anterior end are only traceable as such after unravelling. In young specimens the ureter is whitish and unmistakable as a tube, with recurrent bends at its anterior end. The **sperm sac** most usually lies next to the ureter, but sometimes along the outer side of the vesicula seminalis; it is pale and very thin walled, wide posteriorly and tapers to a point in front, reaching the anterior end of the vesicula seminalis, much of which is hidden by the ureter and the sperm sac. The **vesicula seminalis** is a firm, wide tube, readily identified by its transverse rings; anteriorly it is continuous with the vas deferens which here forms a bend coinciding with the bend in the ureter.

Each of the three structures is intimately attached to the others by connective tissue, which is readily broken down by blunt dissection. In the unravelling process, first separate completely the sperm sac from its connective tissue attachment to the vesicula seminalis, and turn it back. After freeing the main length of the ureter from the vesicula seminalis, examine the relationships of the bends of the ureter and the end of the vas deferens. Note that the loop in the ureter can be lifted free from the adjacent loop of the vas deferens; but it is most important to realise that into the ureter at the bends come delicate ducts from the kidney. Unless great care is exercised at this point, there is a risk of breaking the ducts. If the ureter is kept towards the inner side and the vas deferens and vesicula seminalis are gradually moved towards the outer side, the separation can be effected successfully. Throughout be on the look-out for the **kidney ducts** entering the ureter; four of them will be visible at the anterior end of the ureter.

The fifth kidney duct will be found along the ventral side of the kidney near its outer edge. Posteriorly it turns inwards and joins the end of the ureter. To expose this duct, by blunt dissection carefully break down the connective tissue binding the kidney to the vesicula seminalis. The aim of the dissection is to separate completely from one another the sperm sac, ureter, and vesicula seminalis. It will be noticed that the ureter, posteriorly, passes behind (dorsal to) the vesicula seminalis.

Having completed the unravelling, open the **urinogenital sinus.** The sinus is quite a small chamber, about half an inch ($1\frac{1}{4}$ cm.) long. Insert a blade of the fine scissors into the urinogenital aperture, and cut through the ventral wall of the sinus in the middle line, for no more than half an inch ($1\frac{1}{4}$ cm.). When stretched a little from side to side, the opening of the sperm sac on each side will be seen. On one side, cut open the sperm sac for a short distance from its opening, when you will see the openings of the vesicula seminalis and the ureter. These openings are side by side and form what appears at first sight to be a single opening; but close examination will show that the apparent single opening is really two, separated by a partition. The inner one is that of the ureter and the outer that of the vesicula seminalis. Prove the truth of this by making a very small incision in the wall towards the end of both the ureter and the vesicula seminalis, and in turn pass the seeker through the incisions to their respective openings. You will notice that these apertures open, not exactly into the urinogenital sinus, but into the posterior end of the sperm sac, just before the sinus is formed.

In connection with the male sexual organs, mention of the claspers and siphon must not be omitted. These organs have already been dealt with in some detail on pages 55 and 71.

Drawing.—Make a drawing of the dissection of the male renal and reproductive organs, complete as far as you have proceeded. The ducts of one side should be shown unravelled.

The **kidneys** themselves are deep red organs when fresh, and brownish-red after preservation, and are lobulated

throughout. They extend right to the posterior limit of the body cavity. As already mentioned, the anterior part, which is overlaid by the vas deferens, is not functional as a renal organ, and is degenerate; it is spoken of as the **epididymis.**

In order to examine the vascular supply of the kidneys, it is necessary to remove all structures ventral to them—the ureters, sperm sacs, and vesiculae seminales. Remove the peritoneum which may remain over the surface of the kidneys. In doing so you will probably find that you have entered a blood space between the kidneys. This is the beginning of the **posterior cardinal sinus,** which here is a single vessel. In any case it will be necessary to open the vessel.

On the surfaces of the closely apposed kidneys you will see a number of small holes. These are the **renal veins** which thus contribute to the formation of the posterior cardinal sinus. The veins themselves do not appear outside the kidneys. Follow the sinus forwards with a seeker, and you will find that it branches into two vessels, a right and a left, with only a partition between them. The partition, or septum, may, or may not, be complete.

If the greater part of the tail has not already been cut off, this may now be done, leaving only about two inches (5 cm.) or so. Then from the posterior limit of the body cavity, slice away the ventral muscles of the tail horizontally until you reach the vertebral column. Next, proceed carefully with the slicing so as to remove only the tips of the haemal arches, and so expose the **caudal vein.** Open it, and follow it forwards to the posterior ends of the kidney. Wash thoroughly, and with a seeker you will find that you can pass to either one side or the other of the middle line, for the caudal vein divides into right and left **renal portal veins.**

In the haemal canal, note the **caudal artery** immediately dorsal to the vein. This artery is the posterior continuation of the dorsal aorta.

By separating the kidneys, preferably with the fingers, you will see, in the middle line, lying in the posterior

cardinal sinus, a long narrow body resembling a blood vessel gorged with blood. It is bright red when fresh, and orange coloured after preservation. This is the **inter-renal body,** one of the endocrine ductless glands of the dogfish. It may be in two or more parts, hinting at segmentation.

You have already seen another endocrine gland, the thyroid gland, ventral to the anterior end of the ventral aorta. Still other such glands, the **supra-renal glands,** may be looked for. Follow the instructions given on page 134 in connection with the dissection in the female.

Drawings.—1. Make a drawing of your dissection to show the position and extent of the kidneys in the body cavity, the renal vein openings, the renal portal veins, caudal vein, and inter-renal body.

2. Make a drawing to show the position of the supra-renal bodies.

Laboratory Note.—Make a note in your laboratory note-book on the comparative relationship of the endocrine glands found with the adrenal gland of higher vertebrates.

THE NERVOUS SYSTEM AND SENSE ORGANS

The dogfish is a type in which, because of the cartilaginous character of the skull, the nervous system can be more completely dissected out than in the other vertebrate animals in which bone is developed.

The nervous system consists of the **central nervous system**—the brain and spinal cord—and the **peripheral nervous system**—the nerves, cranial and spinal.

It will be found most convenient to display the cranial nerves first and then the brain. The spinal nerves are more or less uniform in arrangement, and some of the anterior ones are usually seen during the later stages of the dissection.

The Dissection of the Cranial Nerves

The cranial nerves consist of ten pairs. On each side are:—

I. The **olfactory** nerve supplying the olfactory organ.
II. The **optic** nerve supplying the eye.

III. The **oculo-motor** (or **motor-oculi**) nerve supplying the internal (anterior), superior, and inferior recti muscles, and the inferior oblique muscle of the eyeballs.

IV. The **patheticus** nerve supplying the superior oblique muscle of the eyeball.

V. The **trigeminal** nerve supplying the snout and upper and lower jaws.

VI. The **abducens** nerve supplying the external (posterior) rectus muscle of the eyeball.

VII. The **facial** nerve whose branches pass to the snout, orbit, and spiracle.

VIII. The **auditory** nerve supplying the auditory organ.

IX. The **glossopharyngeal** nerve whose branches pass to the first gill cleft.

X. The **vagus** nerve whose branches pass to the last four gill clefts, the lateral line sense organs and the viscera.

The first operation is to remove the skin from the dorsal and lateral surfaces of the head as far back as the pectoral fins. In preserved specimens, the dorsal part of the brain box has usually been removed, exposing the brain within. Place the specimen on the dissecting board ventral side downwards, with its head pointing away from you. Take a large scalpel and, holding it with its back downwards, insinuate the point beneath the skin in the middle line at the edge of the aperture in the cranium (at A in Fig. 51). Cut through the skin only in the middle line to the front of the snout as shown along the line A—C. You will find that, holding the scalpel in the position suggested above, a firm pushing movement forwards will sever the skin easily, and since the skin is cut through from the inside outwards, the edge of the scalpel will not be blunted by the placoid scales.

Now turn the fish round so that the head points towards you, and repeat the operation, following the line B—D in Fig. 51. Then make similar incisions in a transverse direction from D to E and D to F. With large forceps

pick up the corner of the skin at D, and keeping the edge of the scalpel close up against the under side of the skin, cut through the attachments between the skin and the underlying muscles, deflecting the flaps of skin to one side. Provided that the edge of the scalpel is kept close against the under side of the skin, this operation can be carried out quite boldly and rapidly. The only regions where care is necessary are immediately above the gill clefts—here the muscle is soft and there is a danger of the scalpel going too deeply—around the eyelids, particularly the lower one and behind the spiracle. From the lower margin of the orbit the large mandibular and maxillary branches of the fifth cranial nerve emerge, and unless the skin only is removed in this region, there is a possibility of damage to these nerves.

Whilst you are removing the skin, note the numerous ampullae filled with mucus. These are part of the sensory canal system (see page 59).

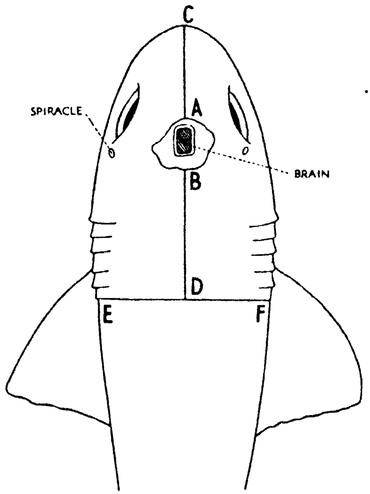


Fig. 51.—Diagram to show incisions for removal of the skin from the dorsal side of the head.

When the flaps of skin have been deflected right up to the lateral margin, they may be cut off with the large scissors.

The Examination of the Eyeball and its Muscles. The removal of the skin from the upper eyelid will have exposed the eyeball to some extent, though it may still not be possible to see down into the orbit. Take hold of the upper margin of the eyeball with the large forceps, and pull it gently outwards from the orbit. If there is still

present—as is usually the case if the removal of the skin has been carefully carried out—a sheet of thin tissue stretching from the eyeball to the margin of the orbit, cut through this with small scissors or scalpel along the orbital margin. It may also be necessary to cut off the tissue along the margin of the orbit—not, however, cutting into the cartilage—and also to cut through the lower eyelid to facilitate moving the eyeball about. You will now be able

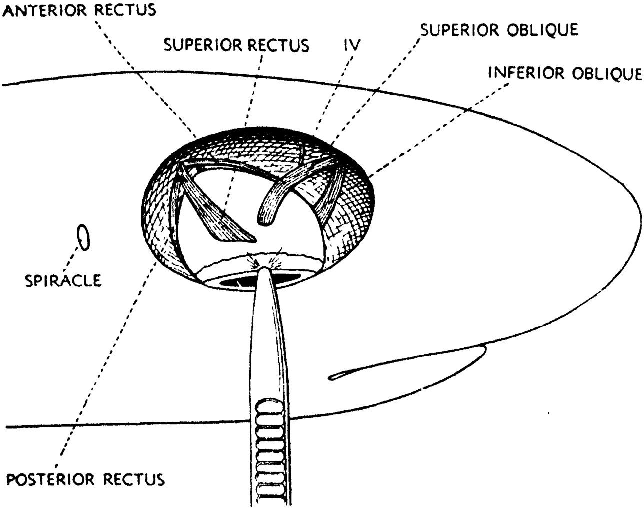


Fig. 52.—The muscles of the eyeball *in situ* in the orbit.

to look right down into the orbit, and, by depressing the eyeball and pulling gently at the same time, to locate the positions of four or five of the six muscles of the eyeball. Take the **recti muscles** first. These all arise from a common point of origin situated at the posterior face of the orbit. The **superior rectus muscle** passes to the upper side of the eyeball and can be seen at once. The **anterior rectus muscle** (internal rectus) lies between the eyeball and the inner face of the orbit. Consequently you will see the

edge of it. By placing a seeker between the muscle and the eyeball and gently pushing the muscle aside, its ribbon shape can be seen. The **posterior rectus** (external rectus) **muscle** lies between the eyeball and the posterior face of the orbit. It can be examined in the same way. The **inferior rectus muscle** lies between the eyeball and the lower face of the orbit, and consequently cannot be seen properly at this stage of the examination.

The two **oblique muscles** arise from a common point of origin on the anterior face of the orbit. The **superior oblique muscle** will be seen passing from this point to the upper surface of the eyeball. To see the **inferior oblique muscle,** it is necessary to cut through the lower eyelid—if this has not already been done—when, by pulling the eyeball backwards and pressing on its anterior face with a seeker, the course of the inferior oblique muscle can be traced from its point of origin to the lower surface of the eyeball.

Drawing.—Make a drawing from the dorsal aspect of the eyeball ***in situ*** in the orbit to show those muscles you have been able to make out.

Laboratory Note.—Make a list of the muscles of the eyeball, their point of origin and distribution.

THE REMOVAL OF THE EYEBALL. [*It is advisable, if the dissection of the epibranchial vessels has already been carried out on the specimen you are using, to select the side opposite to that on which the lower jaw has been cut through, so that the subsequent dissection of the cranial nerves can be continued on this side.*] With the eyeball pulled out as before, take a pair of small scissors, and placing them *closed* between the superior rectus muscle and the eyeball, break down any attachments between the muscle and the eyeball by stroking the muscle on its underside until it is free up to the point where it is inserted into the eyeball. Then cut it off *as close to the eyeball as possible*. Repeat the operation in exactly the same way with the superior oblique muscle. The freeing of these two

muscles will enable you to pull out the eyeball a little farther from the orbit, and enable you to reach more readily the anterior rectus muscle. Release this muscle, and cut it off close to the eyeball. Now pull the eyeball forwards and repeat the operation with the posterior rectus muscle.

By pushing the superior rectus and posterior rectus muscles aside you will now see that any further traction on the eyeball is prevented by the stout optic nerve which passes to the eyeball through the inner face of the orbit. Cut through the nerve close to the eyeball, which can then be pulled almost completely from the orbit, being retained only by the inferior rectus and inferior oblique muscles. These may now be freed and cut off, as were the other muscles, and the eyeball removed completely. In doing so, however, care must be taken to separate from the eyeball the connective tissue which lies between it and the broad band of nerve—the **fifth cranial nerve**—which can now be seen on the floor of the orbit. If this connective tissue is removed with the eyeball then the **buccal branch of the seventh nerve** will be removed with it. Wash out any blood which may be present in the orbit.

THE EXAMINATION OF THE ORBIT. The removal of the eyeball will now have made it possible for you to see into the whole of the orbit and examine the nerves and muscles found in it. The four recti muscles will be seen in the posterior part of the orbit forming a cross-shaped pattern, and the two oblique muscles in the anterior part. Now trace out the nerves which supply these muscles. Seize the free end of the inferior rectus muscle and lift it up, when arising from a point above the base or origin of the muscle will be seen the **third cranial** (oculo-motor or motor-oculi) **nerve** which supplies the superior, inferior, and anterior recti and inferior oblique muscles. From the point where it enters the orbit, trace the short branches which pass to the superior, inferior, and anterior recti muscles. Then note that it traverses the floor of the orbit and ends in the inferior oblique muscle.

The posterior rectus muscle is supplied by the **sixth cranial** (abducens) **nerve.** Usually very little of it can be seen in the orbit, but by seizing the free end of the posterior rectus muscle in the forceps and pulling it forwards, a small trace of the nerve can be sometimes seen right at the point where the muscle is attached to the wall of the orbit.

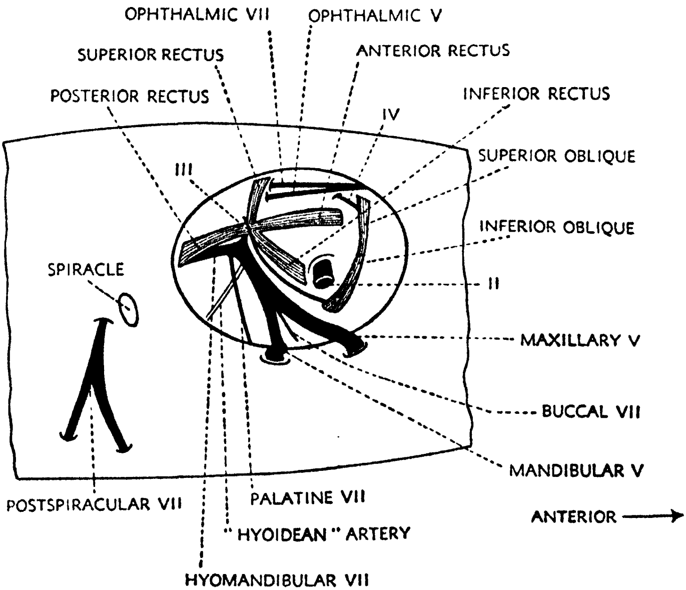


Fig. 53.—Structures visible within the orbit after the removal of the eyeball.

The superior oblique muscle is innervated by the **fourth** (patheticus) **cranial nerve.** Take hold of the superior oblique muscle and pull it away from the orbit when the slender nerve will be seen entering the orbit at a point about half-way along the length of the muscle and passing directly into it.

The remaining cranial nerves which enter the orbit are the **second** (optic), **fifth** (trigeminal), and the **seventh** (facial) nerves. The cut end of the second will be seen in the middle of the inner face of the orbit. The fifth, the largest nerve in the head, has three branches, the **ophthalmic branch** running to the snout, the **maxillary branch** to the upper jaw, and the **mandibular branch** to the lower jaw. The ophthalmic branch enters the orbit in its upper posterior part and runs forwards in contact with the cartilage to a foramen at the anterior end, passing just below the upper margin—or " eyebrow "—of the orbit. Turn the fish up so that you can see the inner face of the upper margin of the orbit. Here will be seen running along the inner orbital face, two nerves, the lower one of which is the **ophthalmic branch of the fifth**; the upper one is the **ophthalmic branch of the seventh,** which will be described later. The largest branch of the fifth nerve enters the orbit through a large foramen in the region of the insertion of the recti muscles, whence it runs across the floor of the orbit as a broad band of nervous tissue. Towards the lower margin of the orbit it will be seen that the nerve divides into the **maxillary branch** which supplies the upper jaw, and the **mandibular branch** to the lower jaw. The seventh cranial nerve has several branches. You have already seen the ophthalmic branch which enters the orbit through a separate foramen a little above and anterior to the corresponding branch of the fifth, and runs alongside it to the anterior face of the orbit. The principal branch of the seventh enters through the same foramen as that of the fifth, but divides immediately into a **palatine branch,** a **buccal branch,** and a **hyomandibular branch.**[1] The palatine branch you will find in the floor of the orbit a little posterior to the broad branch of the

[1] The name given to this branch varies with different writers. By some authors it is called the hyoidean branch, and morphologically it is the nerve supplying the spiracle or hyomandibular cleft, the main part of it passing to the hyoid arch. But since it supplies the lower jaw as well, the name hyomandibular seems the more appropriate.

fifth. It is crossed by what appears to be a fold of skin, beneath which lies the "hyoidean" artery. Near the lower margin of the orbit the nerve bifurcates. The buccal branch will be found usually between the maxillary and mandibular branches of the fifth. It is a delicate nerve, and will only be seen if the directions given above for the removal of the connective tissue on the under side of the eyeball have been followed. The hyomandibular branch traverses the posterior face of the orbit in the direction of the spiracle, the position of which is indicated by a bulge in the posterior part of the orbit. It is the largest of the branches of the seventh nerve, and will be seen in contact with the cartilage along its whole length until it disappears in the tissue at the edge of the orbit.

Drawing.—Within an outline of the head from the lateral aspect, make a drawing of the orbit, showing the structures visible after the removal of the eyeball.

Laboratory Notes.—Make a list of the nerves which enter the orbit and the structures they supply. Also make notes on the precautions to be taken in the removal of the eyeball.

THE TRACING OF THE COURSE OF THE NERVES ENTERING THE ORBIT. **The ophthalmic branches** of Nos. V and VII, after passing through the orbit, pass out on to the surface of the snout, and the portion of the nerves beyond the orbit must now be traced. Take the fish in the left hand, and hold it so that you can see clearly the two nerves within the orbit. Then take a medium sized scalpel and, holding it horizontally with the edge facing the snout, place the point immediately above the seventh nerve at about the middle of its length. Push the point into the cartilage above the nerve, and with a slicing movement remove the cartilage of the "eyebrow" immediately above the nerve, but taking care not to cut into the nerve itself. If this has been done successfully, the cut will have removed the upper part of the foramen through which the nerves pass on their way to the snout. If you cannot see the foramen, then it means that you have not cut away enough of the cartilage, and the operation

should be repeated until the nerves can be seen clearly beyond the edge of the orbit. On the snout the nerves lie in a semi-gelatinous tissue, and quite frequently, since you can see where they emerge from the orbit, the nerves can be seen through the semi-transparent material. But in any case, now that you have exposed the beginning of their course on the snout, it is a simple matter to trace them forward by keeping the back of the scalpel downwards and cutting upwards through the tissue on *each side of the nerve.* As the point of the snout is approached, it will be found that the nerves "fan out" into fine branches, supplying the ampullary sensory canal system.

Now trace the course of the maxillary and mandibular branches of No. V., the former to the upper jaw, and the latter to the lower. In tracing these branches, follow the same kind of procedure recommended above, keeping the back of the scalpel downwards at the side of the nerve, and cutting upwards. After passing over the lower rim of the orbit, the **maxillary branch** will be found to pass along the outer side of the cartilage of the upper jaw, and, if traced far enough, to join up with the terminal branches of the ophthalmic branches of Nos. V. and VII. The **mandibular branch** will, after leaving the orbit, pass backwards behind the mouth angle—hence the recommendation given previously to carry out this dissection on the side opposite to that on which the jaw was cut through during the dissection of the efferent branchial system. Thence, passing somewhat deeply into the tissues, it can be traced along the cartilage of the lower jaw.

Now turn your attention to the **hyomandibular branch** of the seventh cranial nerve. This nerve divides into two branches, the **prespiracular branch** which passes to the front of the spiracle, and the **postspiracular branch,** passing behind the spiracle. The easiest way of dissecting out this nerve is not to follow it from the orbit, but to pick up the postspiracular branch and trace it inwards to the main stem of the hyomandibular. With the edge of the scalpel, gently scrape the surface of the muscle behind and immediately below the spiracle, when the white nerve, the

postspiracular branch, can usually be distinguished at once either on the surface or immediately below it. Clear away any connective tissue from above the nerve so that it is clearly visible. [The only instances where this manoeuvre is not successful at once are those in which—as is sometimes the case due to a blow during capture—there has been extravasation of blood in this region. If this is so, then a little more care is necessary, first in the scraping away of the clotted blood, and then in the removal of the connective tissue.] Having located the nerve clearly, trace it into the orbit in the following manner. Holding the scalpel with the back downwards, place the point close to and parallel to the *posterior* margin of the nerve, and, pushing the point up towards the dorsal surface of the fish, cut boldly upwards, and, tracing the nerve the whole time, continue the operation until the posterior margin of the orbit has been reached and cut through. In this way the branch will have been traced to where it leaves the main stem of the hyomandibular nerve. The only special care which is necessary is to see that the scalpel is parallel to and at the posterior side of the nerve as it is progressively exposed. If this is not followed, then there is danger of cutting through the prespiracular branch or even the hyomandibular nerve itself.

When this has been completed, turn the fish round and trace the ventral portion of the nerve, in the same way, keeping the scalpel parallel to the posterior margin of the nerve the whole time. Soon it will be found that the nerve has branched giving off an **external mandibular branch** which passes to the sensory ampullary system on the under side of the lower jaw. Note that the main branch has passed along the hyoid arch which can be felt beneath it.

Now return to the hyomandibular nerve within the orbit, and, keeping the scalpel on the *anterior* face, trace it in the direction of the spiracle which can be seen bulging into the orbit. Soon, usually at the point where the postspiracular branch arises, a branch, rather more slender than the post-spiracular, will be seen—the **prespiracular**—passing to the

front of the spiracle. The operation of tracing these nerves will have left a mass of tissue standing up between the pre- and post-spiracular branches. This can now be neatly cut off with the scissors so that the nerves stand out clearly exposed.

The tracing of the nerves entering the orbit to their origins in the brain is best left until the remaining cranial nerves have been dissected out.

Drawing.—To the drawing which you have already made of the nerves within the orbit, add the course of the nerves you have now traced.

Laboratory Note.—Make a note on the ease or difficulty you experience in locating the postspiracular branch of the seventh nerve.

THE DISSECTION OF THE NINTH AND TENTH CRANIAL NERVES. The only nerves which remain to be exposed are the eighth, ninth, and tenth. The eighth nerve passes direct from the cranial cavity into the auditory capsule, and you will come across it whilst tracing the ninth and tenth nerves to their origin in the brain. These two nerves, however, for the greater part of their course after leaving the cranium, traverse the anterior cardinal sinus, and the method of exposing them is to lay open this sinus along its whole length. If you are still using the same specimen in which you examined the venous system, the anterior cardinal sinus, on one side at least, will have been opened up. But, if the dissection is being carried out on an undissected specimen—as would be the case in an examination—the position of the anterior cardinal sinus must be located without the rather lengthy procedure adopted during the examination of the venous system. Actually, as you have already seen, the sinus lies above the gill pouches between the outer body wall and the massive muscles in relation with the anterior part of the vertebral column. Its position can be determined by pressing with the tips of the fingers the tissues immediately above the gill clefts, when it will be found that they will give easily with the pressure, whereas a very little nearer

to the middle line the more resistant muscle can be felt. This will give you an indication of where the anterior cardinal sinus lies, and the experienced dissector can lay it open by cutting through the roof with a scalpel. However, it is better to locate the position of the sinus more definitely in order to avoid accidental damage. This may be done in the following manner. Place one blade of your large scissors in the *third* gill cleft and cut up dorsalwards through the tissue immediately above it until the large lateral muscles are reached. In so doing you will cut *across* the anterior cardinal sinus, the cut edges of which

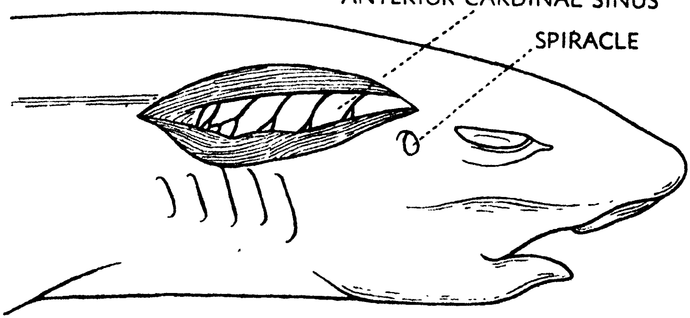


Fig. 54.—The anterior cardinal sinus laid open.

will be found almost immediately above the top of the gill cleft. Put a seeker into the aperture thus formed, and you will find that it will pass forwards to the back of the cranium, and backwards to the region of the pectoral fin. With the seeker directed forwards, cut with the scissors along the line of the seeker through the dorsal wall of the sinus until the cranium is reached, *i.e.* as far as the spiracle. Then repeat the operation with the seeker directed backwards, right to the posterior margin of the sinus. In this way the whole of the sinus will be laid open, and the outer wall can be fastened down. Running across the floor, and passing to the last four gill clefts, will be seen the **branchial**

branches of the tenth nerve. Tracing these nerves towards the inner wall of the sinus, you will find that they join a main stem which lies in close contact with the inner wall, and you can trace this stem to the place where it emerges from the back of the cranium. Having done this, look in the extreme anterior corner of the sinus, and the more slender **ninth nerve** will be seen issuing from the back of the skull a little below and anterior to No. X. On tracing the nerve it will be found to pass to the first gill cleft. Before proceeding further, it is well to expose the main branches of No. X. The three principal branches are the branchial branch to the last four gill clefts, the lateral-line branch to the lateral line, and the visceral branch to the viscera.

The four branches to gill clefts 2-5 will be seen in the floor of the sinus, and arise separately from the main **branchial branch** which runs above them. The **visceral branch** runs alongside the main branchial branch so that it looks as if it were part of it, but before the branch to the last gill cleft is given off, it can usually be detected as a separate nerve passing backwards to the posterior limit of the sinus through which it passes to the general body cavity to supply the heart and the alimentary canal. The extent to which this nerve can be traced will depend upon the specimen. If, as is usually the case, the dissection of the abdominal viscera has been completed, the branches of the visceral nerve will have been destroyed and consequently will not be seen. In an undissected specimen, the course of the nerves can be traced, a **gastric branch** to the stomach and a **cardiac branch** to the heart. The remaining branch, the **lateral-line branch** of the tenth, in the branchial region of the body, lies embedded in the muscles of the inner wall of the sinus. To trace it, hold the fish in the left hand with the head pointing towards you and locate the position of the main stem of No. X. lying closely against the muscles forming the inner wall of the sinus. With the point of the scalpel—keeping the back downwards—free the nerve from investing tissues as near the base of the cranium as possible. Then, keeping the scalpel on the *inner* side of the nerve, continue to free it posteriorly. Soon, usually

before the branchial branch becomes distinct, a branch will be found passing inwards into the muscle. Still keeping the scalpel on the inner side of this branch, trace it for two or three inches by keeping the scalpel parallel to the nerve and cutting upwards through the muscle, etc., in which it is embedded. This nerve is the **lateral-line branch** of No. X., and passes backwards along the whole length of the body to supply the lateral line sensory system.

Having now located the three principal branches of the tenth nerve, the next operation is to trace it and also the ninth nerve to their origins in the brain. This involves the slicing away of the hinder part of the cranium and auditory capsule, and is facilitated if the thick muscle behind the cranium is first removed. Holding the fish in the left hand, and holding the scalpel transversely to the body but parallel to the dorsal surface, slice away the thick muscle backwards to the region of the last gill cleft down to the level of the dorsal surface of the vertebral column, the upper portion of which may be cut through to expose the spinal cord. Now, still holding the fish in the left hand, commence to slice away the cartilage of the hinder part of the cranium in thin slices. In doing this, hold the scalpel parallel to the dorsal surface of the cranium above where the roots of the nerves lie, and take off thin slices until the nerves can be seen showing whitely through the semi-transparent cartilage. During this process you will have cut through the auditory capsule, and in doing so will cut the **semicircular canals** of the **membranous labyrinth**,[1] the positions of which you should note as they appear. As soon as the nerves can be seen through the

[1] It is possible, with care, for you to cut away the whole of the cartilage from around the membranous labyrinth and remove it completely, but this is a lengthy and somewhat tedious dissection which would be out of place here, but if you have time, you might afterwards attempt the dissection on the opposite side. The parts of the membranous labyrinth should, however, be noted as you come across them. You will first of all cut through the vertical **semicircular canals**, and later the horizontal one. Then a space in the cartilage will appear, in which lies the **utriculus**, and finally a larger space in which is found the **sacculus**.

cartilage, then especial care must be exercised to avoid cutting them and also to avoid injury to the brain. Now, instead of slicing horizontally, pare away the cartilage in those places where necessary. Make clean cuts—do not scrape, as this obscures the nerves—and in doing so, observe the following useful precaution. When preparing to cut away a piece of cartilage, push the point of the scalpel into the cartilage in the neighbourhood of the nerve, and, if the nerve is obscured by the knife, then the cut can be made with safety. If, however, you can see the nerve above the point of the blade, then the cut will go too deep, and the point should be withdrawn and a fresh start made. In all these operations it is important to limit the cut to precisely the desired region, and this is facilitated if, with the fish fastened down, in addition to having the forearm resting on the bench, all the disengaged fingers of the operating hand are resting on the specimen, so that movement is restricted to those fingers actually holding the instrument. Also, although your attention is especially fixed on the nerves you are exposing, take care not to damage other nerves which you have already exposed, such as the postspiracular branch of the seventh nerve.

The first nerve to appear will be the tenth, for, as you will have seen in tracing its main stem to the back of the cranium, it is much more dorsally situated than the ninth. As soon as the tenth can be seen, pare away the cartilage around it until it is fully exposed. Then continue to slice away the remainder of the auditory capsule, which lies on the outer side and anterior to it, until the root of No. IX. can be seen, when it may be treated in the same way as you treated No. X. During this operation, especially when clearing away the cartilage in the region of the roots, a short, stout nerve may come into view—the VIIIth or **auditory nerve**—which ends in the membranous labyrinth which, by now, you will have practically destroyed. Continue to cut away the anterior part of the auditory capsule—taking particular care not to injure the seventh nerve—until the hinder part of the brain, where the nerves leave it, is fully exposed.

Having now exposed the roots of the ninth and tenth nerves, all that remains is to clean up the dissection and trace the branches around the gill clefts. This latter dissection is facilitated if some cylindrical object—such as a specimen tube or a round piece of wood—is pushed through the mouth down into the pharynx. In tracing the branchial branches, commence with No. IX. Keeping the back of the scalpel downwards, and first to one side and then the other of the branch which passes to the front of the first gill cleft—the **pre-trematic branch**—cut upwards through the tissues, tracing the nerve as far as possible. [This branch, as is the case with all the pretrematic branches except the last, is rather slender, and usually cannot be traced very far into the gill tissue.] Then do the same for the branch—the **post-trematic branch**—which passes to the posterior side of the gill cleft. This is a rather stouter nerve, and may be traced farther. Now cut away neatly all the tissue—gill filaments, etc.—lying between the two branches, so as to expose the gill cleft fully with the nerve branching around it. Treat each of the branchial branches of the tenth nerve in a similar manner until the whole have been exposed. Finally, clear away all the massive muscle between the lateralis branch and the main stem, and between the lateralis branch and the spinal cord, so that the nerves are clearly visible.

THE EXPOSURE OF THE DORSAL SURFACE OF THE BRAIN. So far, with the exception of the eighth, ninth, and tenth nerves, you have only traced the course of the cranial nerves after they have issued from the cranium. To see where the remainder originate in the brain, it is necessary to expose the whole of its dorsal surface. A beginning has already been made in tracing the roots of Nos. IX. and X., during which operation a portion at least of the hinder part of the cranium has been cut away exposing the hinder part of the brain and the spinal cord. This will serve as the starting point for the complete removal of the roof of the cranium. If the hinder part of the brain has not been completely exposed, do this by slicing the

cartilage of the hinder part of the cranium, holding the scalpel parallel to the surface, and taking care not to injure the underlying brain. When this has been achieved, the removal of the anterior part may be proceeded with. It is best first to remove the middle of the roof of the cranium lying between the orbits and anteriorly between the two ophthalmic branches of Nos. V. and VII., so that you can see clearly into the cranial cavity. The portion between the orbits is cartilaginous, and can be cut through with the scalpel held parallel to the surface and tracing a course parallel to the upper margin of the orbit, taking care not to let the scalpel project too far into the cranial cavity, or otherwise the brain may be injured. The anterior part is membranous—covering the anterior fontanelle—and is readily slit through with the point of the scalpel kept parallel to the ophthalmic nerves. Now the cranial cavity will be exposed and it is well to wash it out thoroughly so that the brain can be seen clearly.

Returning now to the region of the auditory capsule, press the brain aside with the flat of the scalpel, and, arising from the side of the brain a short distance in front of No. IX., will be seen a group of nerves. These are the branches of Nos. V. and VII., and also the root of No. VIII. It is now essential to remove the piece of cartilage between these and No. IX., and in doing so great care is necessary to avoid either cutting or breaking the nerves. First of all cut off the greater part of the four recti muscles which obscure the nerves in this region of the orbit. Then, locating the position of the ophthalmic branches of Nos. V. and VII. in the orbit and in the cranial cavity—they are the two slender, more dorsally placed nerves in the group—carefully cut away the cartilage of the side of the orbit and behind them until the whole of their length can be seen. Now, usually, the common main stem of Nos. V. and VII. can be seen faintly through the cartilage, and this should be pared away until the nerves are exposed.

No further dissection is desirable to see the origins of Nos. II., III., and IV. On looking down into the cranial cavity—and the use of a lens is recommended—and gently

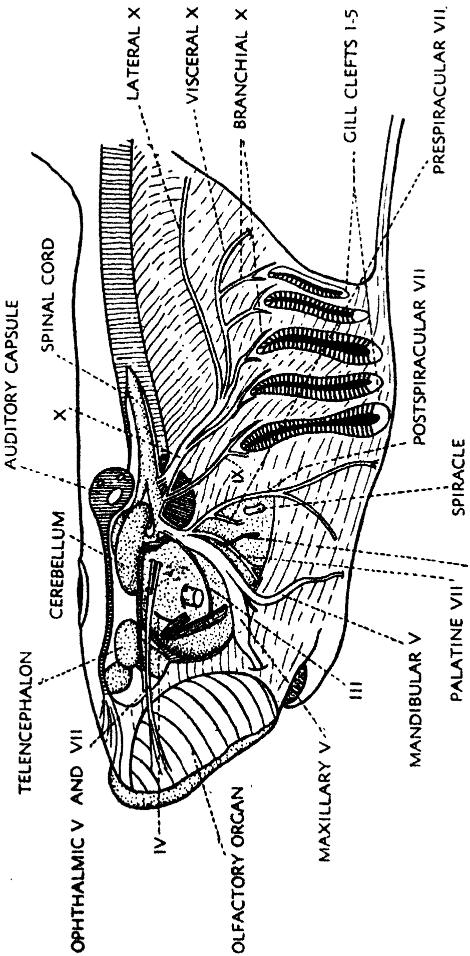


Fig. 55.—The completed dissection of the cranial nerves. (The recti muscles have been removed.)

pushing the brain away from the cranial wall with the back of a scalpel, a slender nerve will be seen—the IVth—arising from the side of the brain and entering the orbit just below the ophthalmic branches of Nos. V. and VII. To see Nos II. and III., it is necessary to push the brain still further away from the side of the cranium, but this must be done with care, otherwise No. IV. may be snapped. Then, lying on the floor of the cranial cavity No. II. will be seen in line with its position in the orbit, and No. III. more posteriorly opposite the point of attachment of the recti muscles.

If desired, the dissection may be completed by the removal of the cartilage covering the lateral portion of the front of the brain and the olfactory organs. In order to preserve the ophthalmic branches of Nos. V. and VII., it is best to detach their branching ends from the front of the snout and, separating them from the underlying tissues, turn them backwards. The cartilage of the anterior part of the cranium can then be easily removed, and the nerves replaced in position.

Drawing.—Within the outline of the anterior part of the body draw as many of the nerves as can be seen in a lateral view.

Laboratory Notes.—Make notes on the positions of those nerves, the origins of which cannot be seen in your drawing.

THE REMOVAL OF THE BRAIN. The procedure to be adopted will depend upon whether the specimen is whole or whether the dissection of the cranial nerves given above has already been carried out, with the consequent exposure of the dorsal surface of the brain.

In the former case, remove the skin from the dorsal surface of the head as directed on p. 142, though in this instance the removal need not be carried so far laterally—just sufficient to bare the roof of the cranium. With the large scalpel held horizontally, slice away the cartilage forming the roof of the hinder part of the cranium, taking care not to damage the underlying brain. Special care need not, however, be given to the cranial nerves. Continue

the removal of the roof of the cranium forwards—here it is largely membranous—until the whole of the dorsal surface of the brain has been exposed. Then proceed as directed in the next paragraph.

If the brain is to be removed from a specimen in which the cranial nerves have been dissected and the dorsal surface of the brain exposed, then with a sharp scalpel cut through the spinal cord about two inches behind the brain, and by passing the point of the scalpel along each side of the severed portion, free it so that it can be lifted up. Do this by seizing it near the cut end with the large forceps, and raise it out of the spinal canal. This will enable you to see clearly underneath the hinder part of the brain, and with the point of the scalpel cut through the roots of the cranial nerves in this region until the brain can be lifted up sufficiently for you to see the pituitary body lying in its depression or fossa. Introduce the point of the scalpel underneath the pituitary body, and lift it up out of its fossa. Continue the freeing operation by cutting through the roots of the nerves until the olfactory lobes are reached.

It is a common convention to remove the olfactory organs along with the brain. This has arisen perhaps because of the intimate relations between these organs and the olfactory lobes of the brain, but it must be clearly understood that they form no part of the brain itself.

If it is desired to remove the olfactory organs with the brain, then, when the stage in the dissection given above has been reached, the brain should be laid back in the cranial cavity, and the freeing of the olfactory organs proceeded with. Each organ consists of a rounded mass still partly or wholly enclosed by the cartilage of the olfactory capsule in accordance with the extent to which the dissection was carried previously. This cartilage must now be cut away until each organ is completely free from its capsule. It will then be found to be still retained in position by its attachment to the tissue surrounding the external nostril. With the large scissors cut cleanly through this attachment at the ventral side of the organ until it is entirely free. Then the whole of the brain and

the olfactory organs may be removed. One precaution is necessary in this operation. The narrow connection between the olfactory lobes and the brain is liable to break if the lobe is made to take the weight of the large organ, so to prevent this, support should be given to the parts while the brain is being lifted out.

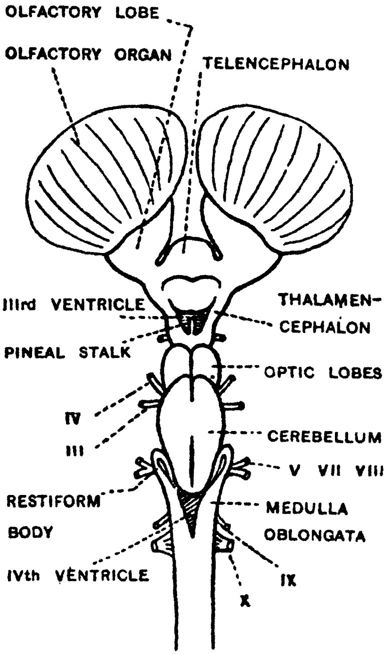


Fig. 56.—The brain and olfactory organs from above.

If you decide not to remove the olfactory organs, then the anterior margins of the olfactory lobes should be carefully separated from the organs and then the brain removed.

After removal, the brain should be placed in a dish of fluid—either water or spirit.

The Examination of the Brain

The brain of the dogfish is built on the plan of the typical vertebrate brain, which consists of the following regions from before backwards: (1) Telencephalon; (2) Thalamencephalon or Diencephalon, which together constitute the Prosencephalon or fore-brain; (3) Mesencephalon or mid-brain; (4) Metencephalon and (5) Myelencephalon, together formed from the hind-brain.

THE DORSAL SURFACE. The **telencephalon** is in the middle line at the extreme anterior end—hence the name.

It is often referred to as the **cerebrum** or **cerebral hemispheres** as in the higher vertebrates. Externally, it shows little indication of division into right and left halves, and therefore the term cerebral hemispheres is less applicable in the case of the dogfish. A pair of slightly raised prominences, however, are sometimes visible, and indicate the paired nature of the cerebrum. Since, in higher vertebrates, the cerebrum is regarded as the seat of intelligence, it would not be expected that in an animal as lowly as the dogfish the telencephalon would be a prominent part of the brain.

Arising by substantial stalks from the sides of the telencephalon are the **olfactory lobes,** which are an outstanding feature of the brain. They are flattened dorso-ventrally, and have a broadly expanded contact with the olfactory organs anteriorly. It is interesting to note that the large development of this part of the dogfish brain would be expected, since the animal has a keen sense of smell on which it depends in its search for food.

Posterior to the telencephalon is the **thalamencephalon,** somewhat triangular in shape, and with a triangular aperture in its roof, leading to a cavity—the **third ventricle.** Sometimes this aperture is covered by a thin membrane, which, in the living or fresh animal, would be red in colour, due to the presence of numerous blood vessels. This membrane is the **anterior choroid plexus.** Lying on this membrane, and sometimes remaining after the plexus has been removed, is a slender structure—looking somewhat like a nerve, for which it must not be mistaken—arising from the hinder end of the thalamencephalon and extending forwards until, if it is complete, it rests on the cerebrum. This is the stalk of the **pineal body.** The body itself was removed by the clearing away of the roof of the cranium.

Behind the thalamencephalon and partly overhung by the anterior part of the cerebellum, are two rounded bodies. These are the **optic lobes,** formed from the mid-brain.

The **cerebellum** is the most prominent part of the brain. Here is the seat of the function of balance and muscular

control, and you are aware of the elaborate sensory system including not only the ear but also that related system known as the lateral line concerned with this function. Free living aquatic conditions of life obviously demand a keen appreciation of balance, hence the great development of the control centre in the brain. The cerebellum has a definite median furrow, and consists of an anterior part overhanging the optic lobes, and a posterior portion partly covering the medulla oblongata—the posterior part of the brain. The **medulla oblongata** is triangular in shape, and in its roof is a triangular aperture leading to the **fourth ventricle.** In the living animal this aperture is covered by the **posterior choroid plexus.** At each side of the medulla is a folded structure, the **restiform body.** The cerebellum and medulla oblongata are formed from the hind-brain.

You should note that the choroid plexus is made up of **pia mater,** a membrane immediately in contact with the brain. It is continuous with the choroid coat in the eye-ball. It is, of course, vascular, as would be expected in the membrane immediately in contact with the brain. Outside the pia mater is the protective membrane called **dura mater,** and this, round the eyeball, becomes the sclerotic coat.

Drawing.—Make a drawing of the brain from the dorsal aspect.

Laboratory Note.—Make a note on the position of the choroid plexuses and whether they were seen in your specimen.

THE VENTRAL SURFACE. Ventrally, the telencephalon with its olfactory lobes is at once recognisable. On this surface the telencephalon has a median furrow dividing it into right and left halves, and posteriorly it narrows into the thalamencephalon. Extending backwards from the hinder end of the thalamencephalon is the **pituitary body,** which is the most striking feature of this aspect of the brain, lying as it does over practically the whole of the middle region. Do not mistake the roots of the optic nerves which form the **optic chiasma** for part of the pituitary body.

The Pituitary Body. There is considerable confusion in the various textbooks regarding the nature of the

ventral appendage of the thalamencephalon. The simplest description is as follows: the pituitary body is the name of the whole appendage, and consists of (1) the **infundibulum,** which is originally a downgrowth from the brain and is median in position; and (2) the **hypophysis,** which is originally an upgrowth from the roof of the stomodoeum, becoming fused with the infundibulum.

The sides of the infundibulum are thickened to form the **lobi inferiores,** situated immediately behind the optic chiasma.

The hypophysis has several lobes which, however, need not concern you in your practical work. At each side is an extension of the floor of the brain which is vascular and wrinkled in form. This is the **saccus vasculosus,** a structure found only in fishes, and whose function is not understood.

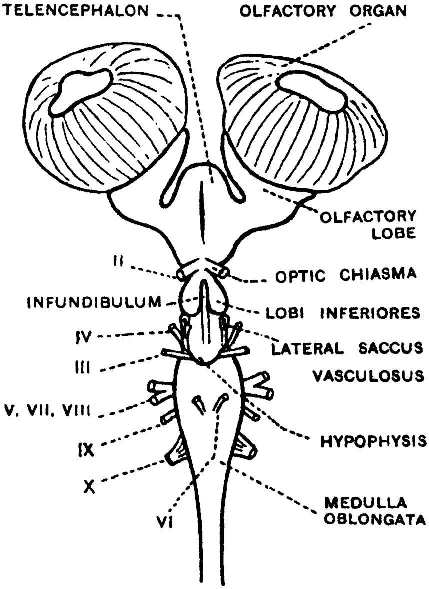


Fig. 57.—The brain and olfactory organs from below.

Projecting from the sides of the brain in the region of the pituitary body, the outer margins of the optic lobes can often be seen.

Behind the pituitary body is the medulla oblongata with the restiform bodies at the sides.

Drawing.—Make a drawing of the ventral surface of the brain.

THE ROOTS OF THE CRANIAL NERVES. The extent to which the roots of the cranial nerves can be seen will depend upon the care which was exercised in cutting through them during the removal of the brain. Their positions are as follows, and they are best seen in the ventral view:—

I. These consist of a number of fibres passing directly from the olfactory lobes into the olfactory organs, and consequently cannot be seen in this external view.

II. These arise from the ventral surface of the thalamencephalon just anterior to the pituitary body, their roots forming the optic chiasma.

III. These arise from the ventral side of the brain in the region of the hypophysis. Lift up the hypophysis and the roots of the nerves will be seen issuing between it and the ventral surface of the brain.

IV. These appear at the side of the brain just where the posterior margin of the optic lobe abuts on the cerebellum. They are very slender nerves, and are frequently lost during the removal of the brain.

V., VII., and VIII. These nerves arise together from the sides of the medulla oblongata in the region of the restiform bodies. They should have been retained fairly completely. As you saw when dissecting them out, V. and VII. branch immediately into an ophthalmic branch and a main stem, the ophthalmic branches being more slender. VIII. is the most posterior of the nerves.

VI. These arise from the ventral side of the medulla oblongata near the mid-line, and at about the level of the posterior margin of the restiform bodies.

IX. These arise from the sides of the medulla oblongata a short distance behind No. VIII.

X. These nerves have several roots joining into a main stem. The roots arise from the side of the medulla oblongata posterior to No. IX.

Drawing.—Put in the roots of the cranial nerves in your drawing of the ventral surface of the brain.

The Cavities of the Brain.—The neural canal of the embryonic neural tube persists in the adult animal as the cavities of the brain and spinal cord. To see these it is best to divide the brain into two by a slicing cut with a razor or sharp scalpel vertically downwards in the median line. Pin down the brain in a dissecting dish under water; it is an advantage to cut off the olfactory organ and part

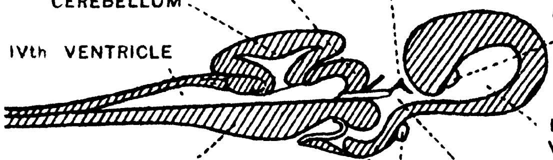


Fig. 58.—Median Longitudinal section of the brain to show the cavities.

of the olfactory lobe. Separate the cut edges so that the cavities can be seen clearly.

With the two cut surfaces before you it is probable that the telencephalon in one will appear solid, whereas in the other it may show a cavity—the **lateral ventricle.** The solid appearance in the one section is due to the presence of a vertical sheet of tissue separating the two lateral ventricles from each other, and it is extremely unlikely that the section will have passed clean through the middle of this sheet. Each lateral ventricle communicates posteriorly with the third ventricle, and laterally with the cavity of the olfactory lobe, the presence of which you can see by examining the cut surface of the lobe. If you

cannot see at once the aperture by which the lateral ventricle communicates with that within the olfactory lobe —it lies in the lateral wall of the ventricle towards its hinder end—then pass in a bristle through the cavity of the olfactory lobe, and see where it enters the ventricle.

By introducing a bristle into the **third ventricle**—that is, the cavity of the thalamencephalon immediately posterior to the telencephalon—and pushing it gently forwards, the aperture between it and the lateral ventricle, the **foramen of Munro,** will be disclosed. This is facilitated by separating the edges of the hinder part of the lateral ventricle when the aperture will be seen at its posterior extremity.

The remaining cavities are easier to make out. The position of the third ventricle has already been indicated. Note that, if the roof is still present, it is thin and may be reddish in colour where it is pushed into the cavity. Also note that the cavity of the third ventricle extends into the infundibulum. The thinness of the wall of the hypophysis as compared with the infundibulum will be at once evident. An extension of the third ventricle also passes into the pineal stalk, but it is very unlikely that you will see this.

The third ventricle is in communication posteriorly with the cavities of the optic lobes. It is at once obvious that these lobes are thickenings of the dorsal part of the mid-brain. Actually, the third ventricle communicates by a narrow channel, the **aqueduct of Sylvius** or **iter**—to give it its full name the " iter a tertio ad quartum ventriculum "—with the fourth ventricle, and the cavities of the optic lobes are extensions laterally from this.

The **fourth ventricle** is the cavity within the medulla oblongata. Note that its roof is also thin—consequently it has usually been torn away—and that the ventral part of the medulla is a thickening of the floor of the hind-brain. The cerebellum is also hollow, being formed by a thickening of the anterior part of the roof of the hind-brain, and its cavity will be found to communicate with that of the fourth ventricle. The cavity of the fourth ventricle is continuous with the central canal of the spinal cord, but

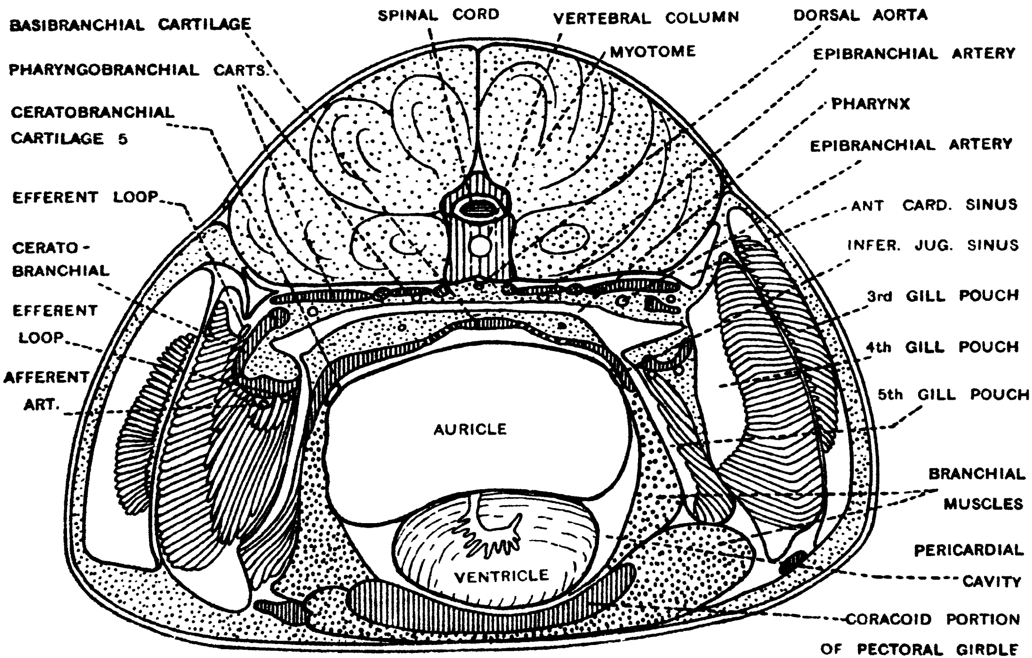


Fig. 59.—Transverse section across the branchial region.

this canal is usually too small to be seen even with the lens, except just where the medulla passes into the spinal cord.

Drawing.—Draw the sectioned surface as you have examined it, and indicate the apertures of those cavities which are not included in the section.

TRANSVERSE SECTIONS

Demonstration sections across the pharyngeal, abdominal, and caudal regions are most instructive, and are commonly used to show the relationships of organs to one another *in situ*.

A fresh undissected specimen is necessary, but needs hardening to facilitate cutting a clean section. A slit may be made in a part of the abdomen which will not come in the section, and 15 per cent. formalin injected to fill the whole body cavity. The specimen is then laid in 15 per cent. formalin, and left there for two or three weeks or more to harden thoroughly. After the skin only has been cut with a scalpel, the rest of the sectioning should be made with a razor, making as few strokes as possible to give a cleanly cut surface to the section. The only troublesome organ is the ovary of mature females; this is almost impossible to harden if mature or nearing maturity. The recognition of blood vessels will be assisted by the use of a seeker or mounted needle; having lost all blood they tend to collapse. The dorsal aorta and cardinal sinuses will be made clearer by a slight stretching of the surface of the section by forceps or seeker.

It is suggested that the points given below should receive attention.

Branchial Region

(1) The great development of the dorsal muscles and their disposition.

(2) The position of the vertebral column with the spinal cord.

(3) The heart showing the large, single, thin-walled auricle (atrium) and thick-walled ventricle.

(4) The position of the skeletal parts should be particularly noted.

(5) The gill pouches will never appear exactly the same in different sections and seldom symmetrical on the two sides, but three gill pouches will generally appear on each side. Note the continuity with the pharynx shown in the case of the fifth gill pouch in Fig. 59.

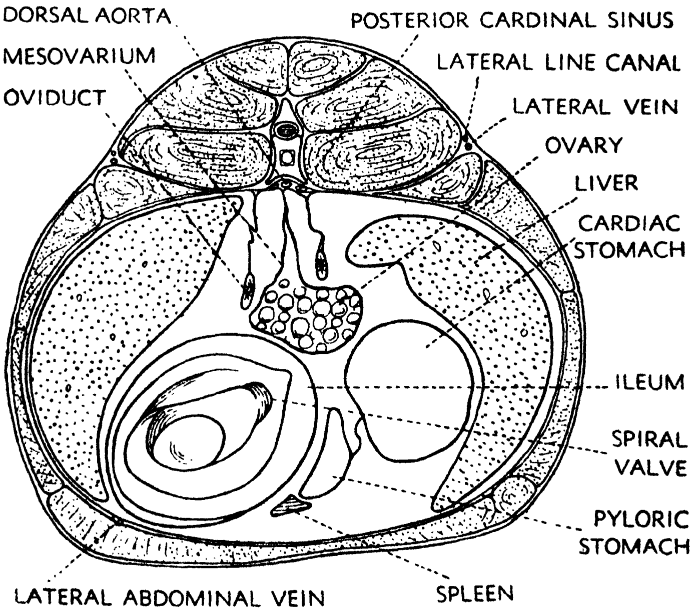


Fig. 60.—Transverse section across the abdominal region.

Abdominal Region

(1) The relative thickness of the body wall dorsally, laterally, and ventrally.

(2) The course of the myocommata.

(3) The relative positions of the vertebral column, spinal cord, dorsal aorta, and posterior cardinal sinuses.

(4) The lateral line sensory canal and the lateral cutaneous vein just beneath it.

(5) The lateral abdominal vein in the ventral body wall.

(6) The suspensories of the various organs from the dorsal body wall.

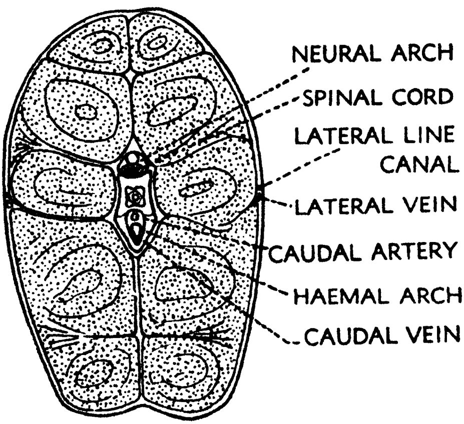


Fig. 61.—Transverse section across the caudal region.

Caudal Region

(1) The position of the vertebral column.

(2) The spinal cord and haemal canal, caudal artery and vein.

(3) The course of the myocommata.

It should be understood that the sections you will examine will not necessarily be exactly like those illustrated here, as the structures present in a section will depend upon where it is cut. The figures therefore must be taken only as a guide.

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